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ABSTRACT

This manual is designed to provide enlisted men with background information that will be useful in preparation for advancement in rating to Gunner's Mate (Guns) 1 and Gunner's Mate (Guns) C and to enable them to perform their duties in these ratings. The manual includes a subject index and numerous diagrams and illustrations. (AG)

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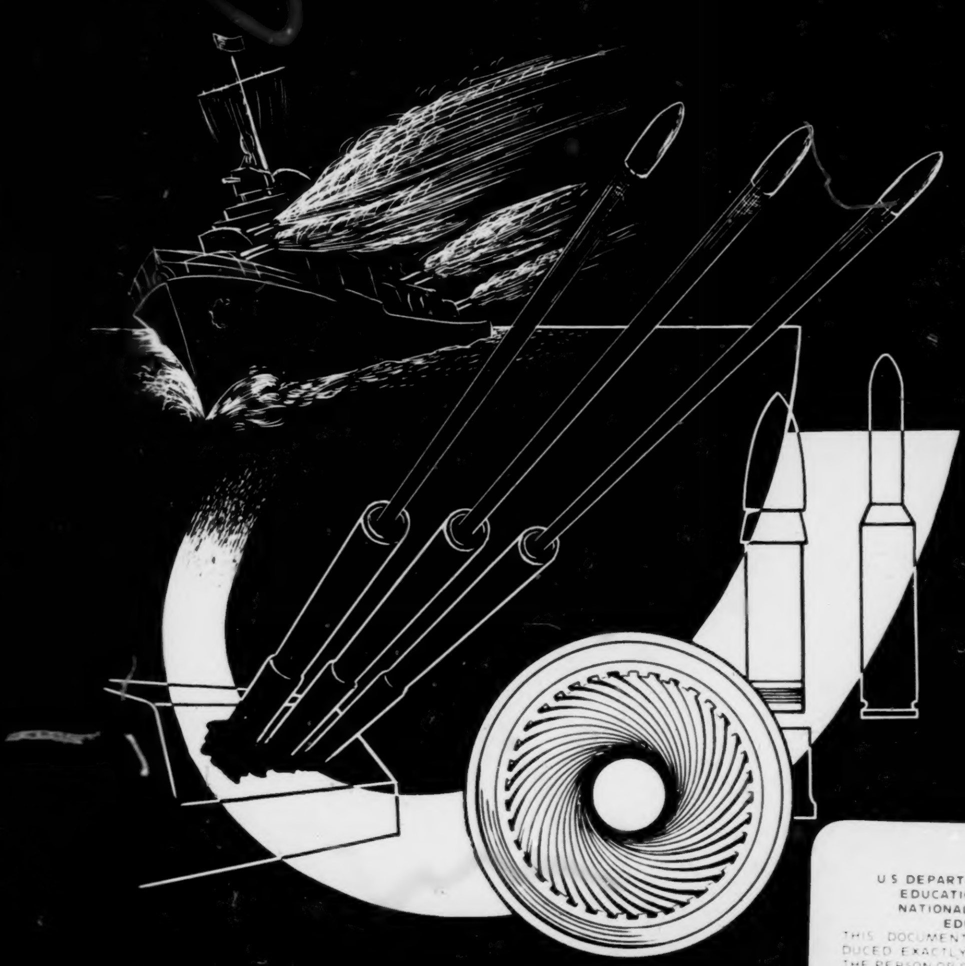

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GUNNER'S MATE G 1 & C

NAVAL TRAINING COMMAND

RATE TRAINING MANUAL NAVTRA 10186-C

ED 082010

PREFACE

This is one of a series of Rate Training Manuals designed to provide enlisted men with background information that will be useful in preparation for advancement in rating, and necessary in the proper performance of their duties. This course was written to serve as an aid for enlisted men of the U.S. Navy and the U.S. Naval Reserve who are preparing for advancement to Gunner's Mate (Guns) 1 and Gunner's Mate (Guns) C. Appropriate sections of the Manual of Qualifications for Advancement, NAVPERS 18068-C were used as a guide in selecting the contents of this text.

This book was prepared for the Naval Training Support Command by the Training Publications Division, Naval Personnel Program Support Activity, Washington, D.C. Technical assistance was provided by the Gunner's Mates School, Great Lakes, Illinois; the Naval Examining Center, Great Lakes, Illinois; and the Naval Ordnance System Command (NAVORDSYSCOM) Washington, D.C.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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NOTE

During the writing of this rate training manual a change in the Manual of Navy Enlisted Classification, NAVPERS 15105-U, was released by the Chief of Naval Personnel. This change, outlined in BUPERS NOTE 1440 of 13 September 1971, promulgated a change of source rating for ASROC Launching Group Maintenanceman from GMG to GMT. The GMG no longer has the responsibility of ASROC system maintenance. All information about the ASROC missile, ASROC Launcher and ASROC missile handling contained in this rate training manual now will be used by personnel in the GMT rate pending revision of Navy training course material. It is anticipated that ASROC maintenancemen will participate for advancement in the GMG rating pending revision of Navy-wide examinations. It is anticipated that ASROC maintenancemen will participate for advancement in the GMT Navy-wide examinations commencing February 1973.

CHAPTER 1

ADVANCEMENT

This rate training manual is designed to help you meet the occupational qualifications for advancement to Gunner's Mate First Class and Chief Gunner's Mate. Chapters 2 through 14 of this manual deal with the technical subject matter of the Gunner's Mate rating. The present chapter provides introductory information that will help you in working for advancement. It is strongly recommended that you study this chapter carefully before beginning intensive study of the chapters that follow.

REWARDS AND RESPONSIBILITIES

Advancement in rating brings both increased rewards and increased responsibilities. The time to start looking ahead and considering the rewards and the responsibilities is right now, while you are preparing for advancement to Gunner's Mate "G" First Class or Chief.

By this time, you are probably well aware of many of the advantages of advancement—higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. By this time, also, you have probably discovered that one of the most enduring rewards of advancement is the personal satisfaction you find in developing your skills and increasing your knowledge.

The Navy also benefits by your advancement. Highly trained ordnance personnel are essential to the functioning of the Navy. By each advancement you increase your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. And, second, you become more valuable as a person who can supervise, lead, and train others and thus make far-reaching and long-lasting contributions to the Navy.

In large measure, the extent of your contribution to the Navy depends upon your willingness and ability to accept increasing responsibilities as you advance. When you assumed the duties of a GMG3, you began to accept a certain amount of responsibility for the work of others. With each advancement, you accept an increasing responsibility in military matters and in matters relating to the occupational requirements of the Gunner's Mate rating.

You will find that your responsibilities for military leadership are, generally speaking, about the same as those of petty officers in other ratings, since every petty officer is a military person as well as a technical specialist. Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. Operating and maintaining the ship's weapons and associated equipment is a job of vital importance, and it's a teamwork job; it requires a special kind of leadership ability that can only be developed by personnel who have a high degree of technical competence and a deep sense of personal responsibility.

At this point, let's consider some of the broader aspects of your increasing responsibilities for military and technical leadership.

YOUR RESPONSIBILITIES WILL EXTEND BOTH UPWARD AND DOWNWARD. Both officers and enlisted personnel will expect you to translate the general orders given by officers into detailed, practical on-the-job language that can be understood and followed, even by relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted men.

YOU WILL HAVE REGULAR AND CONTINUING RESPONSIBILITIES FOR TRAINING. Even if you are lucky enough to have highly skilled and well trained ordnance personnel, you will still find that training is necessary. For example, you will always be responsible for training lower rated men for advancement. Also, some of your best workers may be transferred and inexperienced or poorly trained personnel may be assigned to you. Or a particular job may call for skills that none of your personnel have. These and similar problems require you to be a training specialist who can conduct formal and informal training programs to qualify personnel for advancement and who can train individuals and groups in the effective execution of assigned tasks.

YOU WILL HAVE INCREASING RESPONSIBILITIES FOR WORKING WITH OTHERS. As you advance to GMG 1 and then to GMGC, you will find that many of your plans and decisions affect a large number of people, some of whom are not in your division, and some of whom are not even in the weapons department. It becomes increasingly important, therefore, to understand the duties and responsibilities of personnel in other ratings. Every petty officer in the Navy is a technical specialist in his own field. Learn as much as you can about the work of their ratings, and plan your own work so that it will fit in with the overall mission of the organization.

AS YOUR RESPONSIBILITIES INCREASE, YOUR ABILITY TO COMMUNICATE CLEARLY AND EFFECTIVELY MUST ALSO INCREASE. The basic requirement for effective communication is a knowledge of your own language. Use correct language in speaking and in writing. Remember that the basic purpose of all communication is understanding. To lead, supervise, and train others, you must be able to speak and write in such a way that others can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the Navy way of saying things. Some Navy terms have been standardized for the purpose of ensuring efficient communication. When a situation calls for the use of standard Navy terminology, use it.

Still another requirement of effective communication is precision in the use of technical terms. A command of the technical language of the Gunner's Mate rating will enable you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with the work of his own rating is at a disadvantage when he tries to read official publications relating to his work. He is also at a great disadvantage when he takes the written examinations for advancement in rating. Although it is always important for you to use technical terms correctly, it is particularly important when you are dealing with lower rated men. Sloppiness in the use of technical terms is likely to be very confusing to an inexperienced man.

YOU WILL HAVE INCREASED RESPONSIBILITIES FOR KEEPING UP WITH NEW DEVELOPMENTS. Practically everything in the Navy—policies, procedures, equipment, publications, system—is subject to change and further development. As a GMG1, and even more as a GMGC, you must keep informed about all changes and new developments that might affect your rating or your work.

Some changes will be called directly to your attention, but others you will have to look for. Try to develop a special kind of alertness for new information. Keep up to date on all available sources of technical information. And, above all, carefully read all official instructions and notices dealing with weapons, ordnance, and subjects related in any way to your job on the ship, or which may be of special interest to you or your men.

THE GUNNER'S MATE RATING

Until fairly recently, the rating abbreviation for Gunner's Mate had been GM. This denoted the general rating to which all Gunner's Mates belonged. Belonging to this general rating, which covered many areas and overlapped into many more, the Gunner's Mate became a sort of "jack-of-all-trades" in the ordnance field.

In obtaining all the skills which are necessary to the maintenance and repair of the complex weapons of today's Navy, the GM became a highly competent man. His technical background included an extensive knowledge of hydraulics, the use of a wide variety of tools and test equipment, all types of naval explosives, A/S weapons, and a working knowledge of electricity and electronics.

When guided missiles were added to the fire power of the fleet, the general rating of Gunner's Mate was given the responsibility of maintaining the missile's launching system. This effectively bridged the gap for a period of time. Eventually, however, a decision was made to separate the general rating into two service ratings. One maintains the conventional weapons and their associated equipment and other equipment related to the ASW field such as the Variable Depth Sonar hoisting mechanism. This rating is designated GM(G). The other service rating, GM(M), was assigned to maintain the missile launching systems and associated equipment.

The separation of the two ratings holds true up to and including E-7. At the E-8 and E-9 levels the two are combined into the general rating of Gunner's Mate (GM).

This means that the E-7 Gunner's Mate (Guns), in order to be advanced to E-8, must be prepared to maintain guided missile launching systems. In other words, an E-7 GM(G) taking an examination for E-8 will be examined on qualifications expected of the GM(M) in addition to his own.

The GM(G) rating can be further subdivided into classes, each class being assigned a code number. The purpose of these codes is to assist in identifying personnel in a rating when a broad definition is not sufficient. Code numbers indicate that the person has specialized skills or training. Examples of such codes are GM-0873, assigned to Gunner's Mates who have successfully completed the 5''/54 Mk 42 class "C" school; and GM-0891, given to graduates of the ASROC Launching Group Mk 16 class "C" school. A complete list of the codes is found in the Manual of Navy Enlisted Classifications.

As you have reached the point in your career where you are studying for first class or chief, you are already familiar with the type of work expected of the Gunner's Mate. Boiled down, your duties consist mainly of a maintenance and training. You maintain, test, repair, and perform routine upkeep on gun mounts and associated equipment, and train others in the operation and maintenance of this equipment. As all combatant ships and the majority of auxiliary vessels carry armament, seagoing billets for first class or chief are not very limited. As a senior Gunner's Mate, then, you can expect duty on just about any ship in the Navy, and you must be prepared to maintain any armament aboard.

A limited number of particularly well qualified GM 1 and GMC are given assignments to instruct in Navy schools; to assist in making up the servicewide advancement in rating examinations at the Naval Examining Center, Great Lakes; to assist in the preparation of rate training manuals and other training materials in the Training Publications Division, Naval Personnel Program Support Activity, Washington; and to perform other highly specialized duties where their technical knowledge can be utilized effectively.

The billets mentioned above (mostly professional in nature) comprise only a portion of the billets ashore for the Gunner's Mate. In many instances, your primary duties will not be professional, but military. Examples of this type duty are Armed Forces Police, Recruit Training Commands, and Naval Station Master-at-Arms, to name a few. Your work, if assigned to such duties, will be with people rather than guns. This brings us back to the subject of leadership.

Traditionally the Navy has produced good leaders, and realizing the importance of this trait, General Order No. 21 was issued by the Secretary of the Navy. The purpose of this general order is to achieve an ever-improving state of combat readiness by emphasizing that successful leadership at all levels is based on personal example and moral responsibility, ensuring that all hands are themselves examples of military ideals, and requiring personal attention to and supervision of subordinates. So, you can see that you will be exhibiting leadership at all times—afloat and ashore, and during the conduct of your duties, both military and professional.

You are practicing professional leadership when you supervise your gang of Gunner's Mates in their maintenance activities. Military leadership is what you practice while standing gangway watches, supervising working parties, standing shore patrol, assuming charge of a draft of men, etc.

You will find, or perhaps already know, that as a Gunner's Mate you will be chosen to lead or take charge of many military functions. The Gunner's Mate rating earned the reputation years ago as being a good military man—a good leader. In today's Navy, he still holds this reputation as he follows the examples of those before him—as others will follow you.

REQUIREMENTS FOR ADVANCEMENT

In general, to qualify for advancement you must:

1. Have a certain amount of time in grade.
2. Complete the required military and occupational training manuals.
3. Demonstrate the ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors, NAVPERS 1414/1 (formerly NAVPERS 760).
4. Be recommended by your commanding officer.
5. Demonstrate your KNOWLEDGE by passing a written examination based on (a) the military requirements for advancement and (b) the occupational qualifications for advancement in the Gunner's Mate "G" rating.

FINAL MULTIPLE

Advancement is not automatic. Meeting all the requirements makes you eligible for advancement but does not guarantee your advancement. The number of men in each rate and rating is controlled on a Navy-wide basis. Therefore, the number of men that may be advanced is limited by the number of vacancies that exist. When the number of men passing the examination exceeds the number of vacancies, some system must be used to determine which men may be advanced and which may not. The system used is the "final multiple" and is a combination of three types of advancement systems.

Merit rating system

Personnel testing system

Longevity, or seniority system

The Navy's system provides credit for performance, knowledge, and seniority, and, while it cannot guarantee that any one person will be advanced, it does guarantee that all men within a particular rating will have equal advancement opportunity.

The following factors are considered in computing the final multiple:

Factor	Maximum Credit
Examination score	80
Performance factor (Performance evaluation)	50
Length of service (years x 1)	20
Service in pay grade (years x 2)	20
Medals and awards	15
	185

All of the above information (except the examination score) is submitted to the Naval Examining Center with your examination answer sheet. After grading, the examination scores, for those passing, are added to the other factors to arrive at the final multiple. A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

KEEPING CURRENT ON ADVANCEMENT

Remember that the requirements for advancement may change from time to time. Check with your division officer or with your training officer to be sure you have the most recent requirements when you are preparing for advancement and when you are helping lower rated men to prepare.

To prepare for advancement, you need to be familiar with (1) the military requirements and the occupational qualifications given in the Manual of Qualifications for Advancement, NAVPERS 18068C; (2) the Record of Practical Factors, NAVPERS 1414/1; (3) appropriate rate training manuals; and (4) any other material that may be required or recommended in the current edition of Bibliography for Advancement Study, NAVPERS 10052. These materials are discussed later in the section of this chapter that deals with sources of information.

SCOPE OF THIS TRAINING MANUAL

Before studying any book, it is a good idea to know the purpose and the scope of the book. Here are some points you should know about this rate training manual:

- It is designed to give you information on the occupational (professional) qualifications for advancement to GMG1 and GMGC.
- It must be satisfactorily completed before you can advance to GMG1 or GMGC, whether you are in the regular Navy or in the Naval Reserve.
- It is NOT designed to give you information on the military qualification requirements for advancement to PO1 or CPO. Navy Rate Training Manuals that ARE specially prepared to give information on the military qualification requirements are discussed in the section of this chapter that deals with sources of information.
- It is NOT designed to give you information that is related primarily to the qualifications for advancement to GMG3 and GMG2. Such information is given in Gunner's Mate G 3 & 2, NAVPERS 10185-A.

The occupational Gunner's Mate qualifications that were used as a guide in the preparation of this training course were those promulgated in the Manual of Qualifications for Advancement, NAVPERS 18068-C. Therefore, changes in the Gunner's Mate qualifications occurring after revision C may not be reflected in this training manual. Since your major purpose in studying this training manual is to meet the qualifications for advancement to GMG1 or GMGC, it is important for you to obtain and study a set of the most recent Gunner's Mate G qualifications.

This training manual includes information that is related to both the KNOWLEDGE FACTORS and the PRACTICAL FACTORS of the qualifications for advancement to GMG1 and GMGC. However, no training manual can take the place of actual on-the-job experience for developing skill in the practical factors. The manual can help you understand some of the whys and wherefores, but you must combine knowledge with practical experience before you can develop the required skills. The Record of Practical Factors, NAVPERS 1414/1, should be utilized in conjunction with this training course whenever possible.

This training course deals only with conventional weapons, ammunition, and associated equipment of the type you are expected to become knowledgeable under the Qualifications for Advancement to GMG1 and GMGC. Chapters 2 through 14 of this course deal with the occupational subject matter of the Gunner's Mate rating. Before studying these chapters, study the table of contents and note the arrangement of information. Information can be organized and presented in many different ways. You will find it helpful to get an overall view of the organization of this training course before you start to study it.

SOURCES OF INFORMATION

It is very important for you to have an extensive knowledge of the references to consult for detailed, authoritative, up-to-date information on all subjects related to the military and occupational requirement qualifications of the Gunner's Mate rating.

Some of the publications discussed here are subject to change or revision from time to time — some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been entered.

Official publications and directives carry abbreviations and numbers which identify the source of the document and its subject matter. This training manual, for instance, is NAVPERS 10186-C which means that it is a publication of the Bureau of Naval Personnel, a rate training manual in the Group II rating series. The letter following the numerals designated the edition. Because you should always make it your responsibility to see that you are using the latest edition of any publication or directive, we do not show the final letter when referring to a publication or directive in this manual. ALWAYS USE THE LATEST EDITION.

BUPERS PUBLICATIONS

The BUPERS publications described here include some which are absolutely essential for anyone seeking advancement and some which, although not essential, are extremely helpful.

THE QUALS MANUAL. — The Manual of Qualifications for Advancement, NAVPERS 18068C, gives the minimum requirements for advancement to each rate within each rating. The Quals Manual lists the military requirements which apply to all ratings and the occupational qualifications that are specific to each rating.

The Quals Manual is kept current by means of numbered changes. These changes are issued more frequently than most rate training manuals can be revised; therefore, the training manuals cannot always reflect the latest qualifications for advancement. When preparing for advancement, you should always check the LATEST Quals Manual and the LATEST changes to be sure that you know the current requirements for advancement in your rating.

When studying the qualifications for advancement, remember these three things:

1. The quals are the MINIMUM requirements for advancement to each rate within each rating. If you study more than the required minimum, you will of course have a great advantage when you take the written examination for advancement.

2. Each qual has a designated pay grade — E-4, E-5, E-6, E-7, E-8, or E-9. You are responsible for meeting all quals specified for advancement to the pay grade to which you are seeking advancement AND all quals specified for lower pay grades.

3. The written examinations for advancement to E-6 and above contain questions relating to the practical factors and the knowledge factors

of BOTH military/leadership requirements and occupational qualifications.

A special form known as the RECORD OF PRACTICAL FACTORS, NAVPERS 1414/1, is used to record the satisfactory completion of the practical factors, both military and occupational, listed in the Quals Manual. This form is available for each rating. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries must be made in the DATE and INITIALS column. As a GM 1 or GMC, you will often be required to check the practical factor performance of lower rated men and to report the results to your supervising officer. To facilitate record keeping, group records of practical factors are often maintained aboard ship. Entries from the group records must, of course, be transferred to each individual's Record of Practical Factors at appropriate intervals.

As changes are made periodically to the Quals Manual, new forms of NAVPERS 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement. Keep this in mind when you are training and supervising lower rated personnel. If a man demonstrates proficiency in some skill which is not listed in the Gunner's Mate quals but which falls within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made.

The Record of Practical Factors should be kept in each man's service record and should be forwarded with the service record to the next duty station. Each man should also keep a copy of the record for his own use.

NAVPERS 10052.—Bibliography for Advancement Study, NAVPERS 10052, is a very important publication for anyone preparing for advancement. This publication lists required and recommended rate training manuals and other reference material to be used by personnel working for advancement. NAVPERS 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the NAVPERS number. When using this publication, be SURE you have the most recent edition.

The required and recommended references are listed by rate level in NAVPERS 10052. It is important to remember that you are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Rate training manuals that are marked with an asterisk (*) in NAVPERS 10052 are MANDATORY at the indicated rate levels. A mandatory training manual may be completed by (1) passing the appropriate enlisted correspondence course based on the mandatory manual, (2) passing locally prepared tests based on the information given in the mandatory manual, or (3) in some cases, successfully completing an appropriate Navy school.

It is important to notice that all references, whether mandatory or recommended, listed in NAVPERS 10052 may be used as source material for the written examinations, at the appropriate rate levels.

RATE TRAINING MANUALS.—Rate training manuals are written for the specific purpose of helping personnel prepare for advancement. Some courses are general in nature and are intended for use by more than one rating; others (such as this one) are specific to the particular rating.

Rate training manuals are revised from time to time to bring them up to date. The revision of a rate training manual is identified by a letter following the NAVPERS number. You can tell whether a training manual is the latest edition by checking the NAVPERS number and the letter following the number in the most recent edition of the List of Training Manuals and Correspondence Courses, NAVPERS 10061 (revised).

Each time a rate training manual is revised, it is brought into conformance with the official publications and directives on which it is based but during the life of any edition, discrepancies between the manual and the official sources are almost sure to arise because of changes to the latter which are issued in the interim. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NAVPERS 10052 and therefore is a source used by the Naval Examining Center in preparing the advancement examinations, the Examining Center in preparing the advancement examinations, the Examining Center will resolve any discrepancy of material by using that which is most recent.

There are three rate training manuals that are specially prepared to present information on the military requirements for advancement. They are:

Basic Military Requirements, NAVPERS 10054 (current edition).

Military Requirements for Petty Officer 3 & 2, NAVPERS 10056 (current edition).

Military Requirements for Petty Officer 1 & C, NAVPERS 10057 (current edition).

Each of the military requirements manuals is mandatory at the indicated rate levels. In addition to giving information on the military requirements, these three books give a good deal of useful information on the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead other men; and how to meet your increasing responsibilities as you advance.

Some of the rate training manuals that may be useful to you when you are preparing to meet the occupational qualifications for advancement to GM 1 and GMC are discussed briefly in the following paragraphs. For a complete listing of rate training manuals, consult the List of Training Manuals and Correspondence Courses, NAVPERS 10061 (revised).

Basic Handtools, NAVPERS 10085-A. Although this training manual is not specifically required for advancement in the Gunner's Mate rating, you will find that it contains a good deal of useful information on the care and use of all types of handtools and portable power tools commonly used in the Navy.

Blueprint Reading and Sketching, NAVPERS 10077-C, contains information that may be of value to you as you prepare for advancement to GMG 1 and GMGC.

Mathematics, Vol. 1 NAVPERS 10069 and Mathematics, Vol. 2, NAVPERS 10071. These two training manuals may be helpful if you need to brush up on your mathematics. Volume 1, in particular, contains basic information that is needed for using formulas and for making simple computations. The information contained in volume 2 is more advanced than you will need for most purposes, but you may occasionally find it helpful.

Gunner's Mate G 3 & 2, NAVPERS 10185-A. Satisfactory completion of this training manual is required for advancement to GM 3 and GM 2. If you have met this requirement by satisfactorily completing an earlier edition of Gunner's Mate G 3 & 2, you should at least glance through the -A revision of the manual. Much of the information given in this edition of Gunner's Mate G 1 & C is based on the assumption that you are familiar with the contents Gunner's Mate G 3 & 2, NAVPERS 10185-A.

Rate training manuals prepared for other Group II (ORDNANCE) ratings are often a useful source of information. Reference to these training manuals will increase your knowledge of the duties and skills of other men in the weapons department. The manuals prepared for Fire Control Technician and Gunners Mate Missile's are likely to be of particular interest to you.

OFFICER TEXTS. — Officer texts that you may find helpful when you are preparing for advancement to GMG 1 and GMGC include Principles of Naval Ordnance and Gunnery NAVPERS 10783 and The Weapons Officer NAVPERS 10867.

CORRESPONDENCE COURSES. — Most rate training manuals and officer texts are used as the basis for correspondence courses. Completion of a mandatory training course can be accomplished by passing the correspondence course that is based on the training manual. You will find it helpful to take other correspondence courses, as well as those that are based on mandatory training manuals. For example, the completion of the correspondence course based on Principles of Naval Ordnance and Gunnery is strongly recommended for personnel preparing for advancement to GM 1. Taking a correspondence course helps you to master the information given in the training manual or text and also gives you a pretty good idea of how much you have learned from studying the book.

OTHER BUPERS PUBLICATIONS.—Additional BUPERS publications that you may find useful in connection with your responsibilities for leadership, supervision, and training include the Manual for Navy Instructors, NAVPERS 16103-C, and the Naval Training Bulletin, NAVPERS 14900 (published quarterly).

NAVSHIPS PUBLICATIONS

A number of publications issued by the Naval Ships Systems Command will be of interest to you. While you do not need to know everything that is given in the publications mentioned here, you should have a general idea of where to find information in NAVSHIPS publications.

The NAVSHIPS Technical Manual, NavShips 250-000, is the basic doctrine publication of the Naval Ships System Command. The Manual is kept up to date by means of quarterly changes. All copies of the Manual should have all changes made in them as soon as possible after the changes are received.

Beginning with the quarterly changes dated 15 July 1963, NAVSHIPS began to renumber individual chapters in the NAVSHIPS Manual according to the Navy-Marine Corps Standard Subject Classification System. Under this system, all chapters of the Manual will eventually be part of the 9000 series which identifies ship design and ship's material subject groups. When all chapters have been renumbered to conform to the 9000 numbering system, the old chapter numbers will be eliminated. In the meantime, you will have to consult the sheets in the front of the first volume of the Manual which cross-reference the new numbering system and the old. Some of the Manual chapters remain in their old positions, so the new and the old numbers have a definite relationship to each other. For example, the old chapter 51 will in time be renumbered as 9510, and the old chapter 48 will be renumbered as 9480. However, some of the chapters will be moved to new locations, as well as being renumbered; in these cases, there is no clear relationship between the old numbers and the new. For example, the old chapter 6 has been moved to a new location and is now numbered 9004.

The following chapters of the NAVSHIPS Manual are of particular importance to you.

Chapter	Title
9000	General
9090	Locking Procedures and Torque Wrenches for Threaded Fasteners
9480	Piping Systems
9690	Electrical Measuring and Test Instruments
9710	Fire Control Installation
9780	Ammunition Handling and Stowage
9930	Fire Fighting-Ship
9300	Stowage of Safe, Semisafe, and Dangerous Materials
9720	Turrets and Gun Mounts
9380	Ventilating, Air Conditioning

NAVORD PUBLICATIONS

A number of publications issued by the Naval Ordnance Systems Command will be of interest to you. While you do not need to know everything that is given in the publications mentioned here, you should have a general idea of where to find information in NAVORD publications. You will find that the Ordnance Pamphlet (OP) is the publication most often referred to in this text as a source of amplifying information. OPs are the basic type of technical publications issued by the Naval Ordnance Systems Command. The equipment OP (which is the one you will most generally use) provides detailed instructions on operational theory, physical description of components, installation, maintenance, repair, and safety precautions, for each item of ordnance equipment.

NAVORD OP O is a publication index for all Naval Ordnance System Command Ordnance Publications. It lists OPs and ODs (Ordnance Data) which are current, under preparation, cancelled and obsolete.

NAVORD OD 39397 also is an index for ordnance publications but only for conventional ordnance. It also lists Army TMs and FMs used for small arms maintenance.

Another source of information referred to in this text are INSTRUCTIONS issued by the Naval Ordnance Systems Command. The purpose of these instructions is to pass out the details concerning NAVORD policy in matters of operation and maintenance. NAVORD instructions are listed in an index of Navy Directives NAVPUBINST 5215.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the United States Navy Film Catalog, NAVAIR 10-1-777 (formerly NAVWEPS 10-1-777), published in 1969. Copies may be ordered in accordance with the Navy Stock List of Forms and Publications, NAVSUP 2002. Monthly supplements to the Film Catalog are distributed to catalog holders.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed.

CHAPTER 2

SYNCHROS AND SERVOSYSTEMS

Synchros are used in servosystems to control the position and movements of computers, fuze setters, sightsetting equipment and the power drives of gun, turret, rocket, and missile launchers. Synchros are used as position-sensing devices to convert mechanical signals to electrical signals or to convert electrical signals to mechanical signals. Synchros are also used in servosystems for rapid data transmission between components of a ship's weapon system.

It is beyond the scope of this book to examine each type of synchro individually. The purpose of this chapter is to provide extensive information on synchros and servosystems as they are related to ordnance equipment. Additional references on the construction and principles of operation, as well as the basis of operation of servosystems, should be made to Synchro, Servo, and Gyro Fundamentals, NAVPERS 10105, and United States Navy Synchros, Description and Operation Handbook MIL-HDBK-225 (AS) as well as the review of ordnance application of synchros in GMG 3/2, NP 10185-A. We begin this chapter by first reviewing some of the information presented in the reference publications.

SYNCHROS

Synchros are seldom used alone. They work in teams and when two or more synchros are interconnected to work together, they form a synchrosystem. Such a system may, depending on the types and arrangement of its components, be put to uses which vary from positioning a sensitive indicator to controlling the motors which move a gun mount weighing many tons. If the synchrosystem provides a mechanical output which does the actual positioning, as in the case of the indicator, it is a torque system. If it provides an electrical output which is used only to control the power which does the mechanical work, it is a control system. Control synchros are usually part of a larger system called a servo (automatic control) system. In many cases, the same system is called upon to perform both torque and control functions. Individual units are designed for use in either torque or control systems. Some torque units may be used as control units, but control units cannot replace torque units.

FUNCTIONAL CLASSIFICATION OF SYNCHROS

Synchro units are grouped according to their intended function. The seven common types, or functional classifications, are briefly described here. These types are listed in Table 2-1 with their military abbreviations and their input and outputs, and will be discussed further later in this chapter.

Torque Transmitter

A torque transmitter is a unit which electrically transmits angular information according to the physical position of its rotor with respect to its stator. The rotor position is determined mechanically, or manually, by the information to be transmitted; the end result is the transformation of angular data into corresponding electrical values. Torque transmitters are normally connected to torque receivers, torque differential receivers, or torque differential transmitters; under certain conditions they may be used as control transmitters.

Control Transmitter

Except for being connected only to control transformers or control differential transmitters, control transmitters perform the same function as torque transmitters.

Table 2-1.—Synchro functional classifications

FUNCTIONAL CLASSIFICATION	MILITARY ABBREVIATIONS	INPUT	OUTPUT
Torque Transmitter	TX	Rotor positioned mechanically or manually by information to be transmitted	Electrical output from stator identifying rotor position supplied to torque receiver, torque differential transmitter, or torque differential receiver
Control Transmitter	CX	Same as TX	Electrical output same as TX but supplied only to control transformer or control differential transmitter
Torque Differential Transmitter	TDX	TX output applied to stator; rotor positioned according to amount data from TX must be modified	Electric output from rotor (representing angle equal to algebraic sum or difference of rotor position angle and angular data from TX) supplied to torque receivers, another TDX, or a torque differential receiver
Control Differential Transmitter	CDX	Same as TDX but data usually supplied by CX	Same as TDX but supplied only to control transformer or another CDX
Torque Receiver	TR	Electrical angular position data from TX or TDX supplied to stator	Rotor assumes position determined by electrical input supplied
Torque Differential Receiver	TDR	Electrical data supplied from two TDX's, two TX's or one TX and one TDX (one connected to rotor, one to stator)	Rotor assumes position equal to algebraic sum or difference of two angular inputs
Control Transformer	CT	Electrical data from CX or CDX applied to stator; rotor positioned mechanically or manually	Electrical output from rotor (proportional to sine of the difference between rotor angular position and electrical input angle)

12.328

Torque Differential Transmitter

A torque differential transmitter electrically transmits angular information equal to the algebraic sum or difference of the electrical input supplied to its stator from a torque transmitter, and the angular position of its rotor with respect to its stator. The rotor is positioned to modify or correct the data from the torque transmitter by some desired amount. The electrical output of this unit will be applied to a torque receiver, another torque differential transmitter, or a torque differential receiver.

Control Differential Transmitter

This is functionally the same as the torque differential transmitter except that it is used in control rather than torque systems.

Torque Receiver

A unit whose rotor assumes an angular position determined by the electrical input supplied to its stator from a torque transmitter or torque differential transmitter. For proper operation, the rotor must be connected in parallel with the rotor of the associated torque transmitter, and both synchros energized from the same power source.

Torque Differential Receiver

A unit whose rotor assumes a physical position determined by the algebraic sum or difference of the electrical inputs supplied from two torque transmitters, two torque differential transmitters, or one torque transmitter and one torque differential transmitter.

Control Transformer

A unit which, when supplied with electrical information from a transmitter or differential transmitter, produces an electrical output proportional to the sine of the difference between the control transformer rotor angle and the angle represented by the electrical input.

Now, let's start putting some of these synchros together and see how they work in synchrosystems.

TORQUE SYNCHROSYSTEMS

The individual synchros which make up a torque system are designed to meet the demands placed on them by the mechanical load, which such a system is expected to handle.

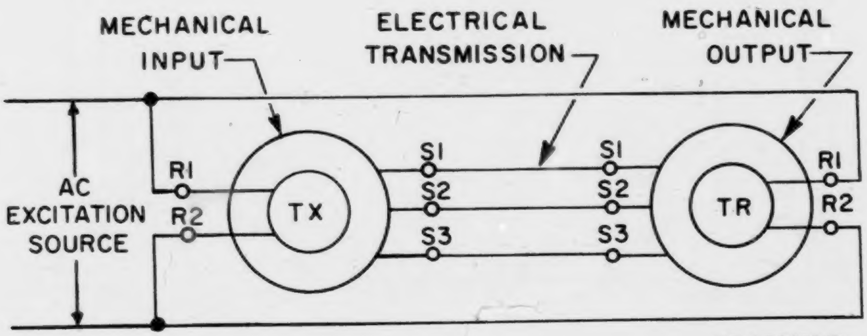
TRANSMITTER AND RECEIVER

The simplest synchrosystem consists of one torque transmitter and one torque receiver connected in parallel (fig. 2-1).

It should be emphasized here that the chief difference between the transmitter and receiver is one of function. The transmitter is the unit whose shaft is turned; the receiver is the unit whose shaft follows. Remember, they are not always interchangeable. Electrically they are identical, but the receiver usually has an inertia damper and certain other refinements which are not present in the transmitter. In the following examples, forces equal and opposite to those turning the receiver rotor are present in the transmitter but do not affect its rotor position because the rotor is not free to turn. In practice, the transmitter rotor is mechanically connected, usually by gears, to the mechanism furnishing the information to be transmitted.

The outstanding characteristic of the transmitter-receiver system is that, as soon as both rotors are connected in parallel to the same a.c. source, the receiver rotor assumes and holds the same electrical position as the transmitter rotor. Naturally, because of phase relationship, the transmitter and receiver are energized from the same a.c. source, otherwise the system could not function properly. If the transmitter is positioned at 0°, the receiver rotor turns to and remains at 0°. If the transmitter is turned to 30°, the receiver turns with it to 30°.

An example of using a simple synchrosystem would be to indicate the position of a controlling director. A synchro generator (TX) is connected mechanically to a controlling director and connected electrically to a synchro receiver (TR) located in the indicating section of a gun/missile plotting room or weapons control station. The indication would be in the form of dial readings mechanically connected to the rotor of the TR.



12.169(53C)

Figure 2-1.—External connections of a transmitter-receiver system.

Rotors in Corresponding Positions

Let's consider the conditions existing in the transmitter-receiver system shown in figure 2-2. Notice that both transmitter and receiver rotors are at 0°. In the transmitter, a maximum of 52 volts is induced in the S2 coil by the alternating magnetic field of the rotor coil because the coupling between these two coils is as the cosine of the rotor angle from the maximum position angle. At 0° the 52-volt maximum is induced in the S2 coil. Since the coils are mechanically positioned to 120° apart, only 26 volts are induced in the S1 and S3 coils. Since the receiver is electrically identical to the transmitter and the two rotors are connected in parallel, the voltage induced in each receiver stator coil exactly equals that of the corresponding transmitter stator coil. Notice, however, that in each case it also opposes the transmitter coil voltage. The transmitter and receiver are like two a.c. generators producing equal voltage but working against each other. No current can flow in the transmitter through S1 and S2, or S3 and S2, because in the receiver equal and opposite voltages across S1 and S2, and across S3 and S2, oppose the current flow. In each complete electrical stator circuit of the system the sum of the voltages is zero. No current flows in the stator coils to establish a magnetic field, and therefore no force is exerted on the rotors.

The fact that the rotors in this example are at electrical zero is not important. Similar static conditions result from any angular rotor position so long as it is the same for both rotors.

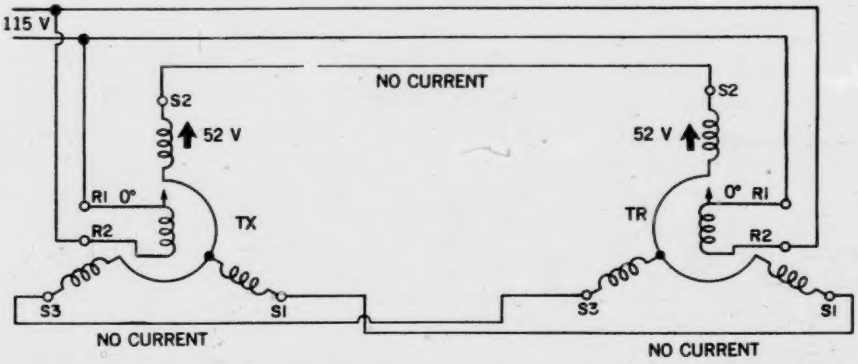
Rotors Not in Corresponding Positions

Now assume that the transmitter rotor is suddenly turned 30° (fig. 2-3). The induced voltages across S2 and S3 immediately drop because couplings to the rotor have been decreased. Increased couplings increase the voltage across S1. The balance between transmitter and receiver stator voltages has been destroyed, and current flows in each stator circuit in direct proportion to the voltage unbalance existing in that circuit.

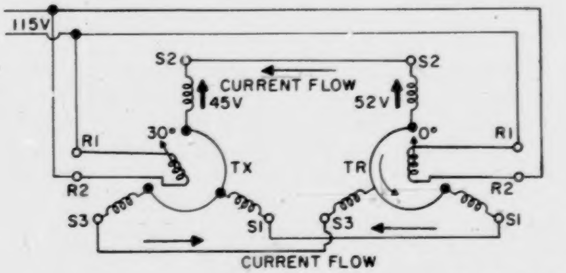
Current, now flowing through the circuits, produces magnetic fields around the receiver stator and rotor coils. The stator and rotor of the receiver, now acting as electromagnets having polarity, act according to the familiar law—like poles repel and unlike poles attract—and the rotor is turned to 30°. At this point, the receiver-induced stator voltages are equal to those of the transmitter and the receiver rotor remains in this position corresponding to that of the transmitter. The same general idea works in any case where the two rotors are in different positions, regardless of what those individual positions may be.

Reversing Direction of Receiver Rotation

When the teeth of two mechanical gears are meshed, the gears turn in opposite directions. If a third gear is added, it turns in the same direction as the first. This is important here because synchro torque receivers are often connected through a train of mechanical gears to the device which they operate, and whether or



53.11(53C)
Figure 2-2. — Internal conditions in TX-TR system with rotors in correspondence.



53.12(53C)
Figure 2-3. — Internal conditions in TX-TR system with rotors not in correspondence.

not the device turns in the same direction as the receiver rotor depends on whether the number of gears in the train is odd or even.

The important thing, or course, is to move the dial or other divice in the proper direction, and even when there are no gears involved, this may be opposite to the direction in which the receiver rotor of a normally connected system would turn.

Either of these two factors, and sometimes a combination of both, may make it necessary to have the transmitter turn the receiver rotor in a direction opposite to that of its own rotor. This is accomplished by reversing the S1 and S3 connection of the transmitter-receiver system, so that S1 of the transmitter is connected to S3 of the receiver, and vice versa.

With both rotors at 0°, conditions within the systems remain the same as with normal stator connection, since the rotor coupling to S1 and S3 are equal. But suppose the transmitter rotor is turned counterclockwise to 60° (figure 2-4). In the transmitter, maximum rotor coupling induces maximum voltage across S1, which causes maximum current to flow through S3 in the receiver. The magnetic forces produced turn the receiver rotor clockwise into line with S3, the rotor's 300° position, at which point the rotor again induces voltages in its stator coils equal to those of the transmitter's coils to which they are connected. Notice that only the direction of rotation changes, not the amount; 300° is the same as -60°.

It is important to emphasize here that the S1 and S3 connections are the only ones ever interchanged in a standard synchro system. Since S2 represents electrical zero, changing the S2 lead would introduce 120° error.

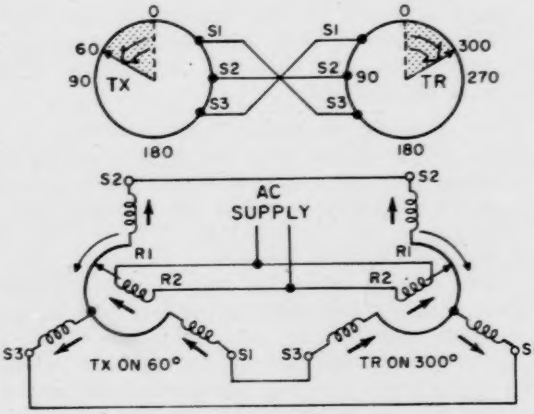
Why There Is No Torque At 180°

Since the stator current increases with the difference in rotor position, and since the magnetic fields of the stators increase in strength with the stator current, it appears the torque, or turning force, exerted by the receiver's shaft should be greatest when the transmitter and receiver rotors are 180° apart—but exactly the opposite is true. The torque, under these circumstances, becomes zero.

Since all the voltages aid each other, strong currents flow in all three stator leads. Obviously, these strong currents produce powerful magnetic forces. But powerful as they are, the forces exerted on the rotor work against each other in such a way that their effects are equal and opposite. In actual situations, the two shafts do not ordinarily stay in these positions unless held there. The slightest displacement of either one destroys the balance, and they are rapidly returned to corresponding positions.

TORQUE SYNCHROSYSTEMS CONTAINING DIFFERENTIAL UNITS

The demands on a synchrosystem are not always so simple as the positioning of an indicating device in response to the information received from a single source. For example, an error detector used in checking fire control equipment employs a synchrosystem to determine the error in a gun turret's position with respect to the



53.14(53C)
Figure 2-4.—Effect of reversing S1 and S3 connections between TX and TR.

training order supplied by a dummy director. In order to do this, the synchrosystem must accept two signals, one containing the training order and the other giving the turret's actual position. The system must then compare the two, and position an indicator to show the difference between them, which is the error.

Obviously, the simple synchro transmitter-receiver systems considered up to this point could not handle a job of this sort. A different type of synchro must be included in the system, one which can accept two position-data signals simultaneously, add or subtract the data, and furnish an output proportional to the sum or difference which it finds.

This is where the synchro differential comes into the picture, because it can perform all three of these functions.

Differential Units

A mechanical differential connects three shafts together so that the rotation of any one shaft is either the sum of, or the difference between, the rotation of the other two. Synchro differentials are similar in operation. Differentials operate either as transmitters, one electrical and one mechanical input which produces one electrical output, or as receives with two electrical inputs which produce one mechanical output. In differentials, both rotor and stator windings consist of three Y-connected coils.

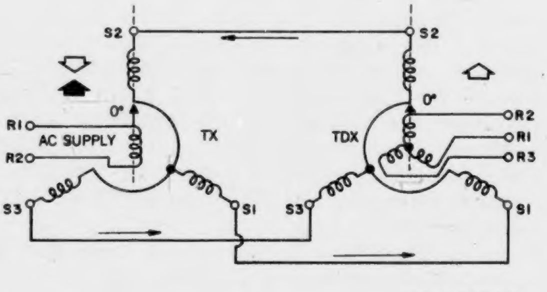
The stator of a differential is similar to that of the transmitter and receiver discussed in preceding sections of this chapter, but the rotor is totally different. It is a slotted symmetrical drum with three coils to match the stator winding as closely as possible.

It is assumed, in the schematic diagrams of synchro differentials, that the three rotor coils turn around an A axis in the center of the diagram, the electrical position of the rotor being shown by the arrow on the R2 lead. If a.c. current is flowing in either the stator or rotor coils, the voltage induced in the other group depends on the position of the rotor, since this determines how closely the coils are coupled to one another. If all circuits are complete, currents flow in both rotor and stator coils, and these currents generate individual magnetic fields around each coil. The strength and direction of the magnetic field are determined by the strength and direction of the current flow in the coil.

Resultant Magnetic Fields in a Transmitter and Differential Transmitter

Thorough analysis of the interaction of a servosystem's magnetic fields is extremely complex, but the overall effect is relatively simple. When current flows in the stator coils of any synchro, individual magnetic fields are produced around each coil. Lenz's law states that when current is flowing as the result of an induced voltage, the magnetic field which the current produces opposes the magnetic field that induced the voltage. In a synchro transmitter, the stator voltages are induced by the fluctuating magnetic field of the rotor. The individual magnetic fields around the stator coils therefore oppose the field of the rotor, and the stator coils are so wound and positioned that the individual fields combine to produce a resultant stator field which is opposite to the field of the rotor.

Now assume that the stator leads of a TX (torque transmitter) are connected to the corresponding stator leads of a TDX (torque differential transmitter), as shown in figure 2-5. The resultant stator field, shown by an open arrow, produced in the TX directly opposes the TX rotor field, shown by a solid arrow. Since corresponding stator coils of the two units are in series, for example, S2 of the TX in series with S2 of the TDX, the current flow produces a resultant stator field of equal strength in the TDX. However, currents in corresponding stator coils of the TDX are opposite in direction. The direction of the stator field in the TDX is therefore opposite to the direction of the TX stator field, but identical to the direction of the TX rotor field.



53.15(53C)
Figure 2-5.—Position of TDX stator field when TX rotor is at 0°.

The result is that the TDX stator field acts upon the TDX rotor just as the TX rotor field acts upon the TX stator. If the stator coils of a TR (torque receiver) are connected to corresponding rotor coils of the TDX, rotating the stator field of the TDX with respect to the rotor produces the same effect in the TR as turning the rotor of a TX in previous examples.

Before considering such an arrangement, however, it must be made clear that the controlling relationship in the TDX is the position of the TDX stator field with respect to the rotor, not with respect to the TDX stator. Suppose that the TX rotor in the previous example is turned to 75°, and the TDX rotor to 30° (fig. 2-6). The TDX stator field is now positioned at 75° with respect to S2, but the angle at which it cuts the TDX rotor is 45°, using the R2 axis as a reference. This is the angle which determines the signal that the TDX transmits. Notice that turning the TDX rotor 30° counterclockwise decreases the angle between the TDX stator field and R2 by that amount.

How the Differential Transmitter Subtracts

The manner in which the torque system containing a TDX subtracts one input from, or adds to the other can be figuratively described as the positioning of magnetic fields. Figure 2-7 shows such a system connected for subtraction. A mechanical input of 75° is applied to the TX and converted to an electrical signal which the TX transmits to the TDX stator. The TDX subtracts its own mechanical input from this signal, and transmits the result to the TR, which provides the torque system's mechanical output in the position of its rotor.

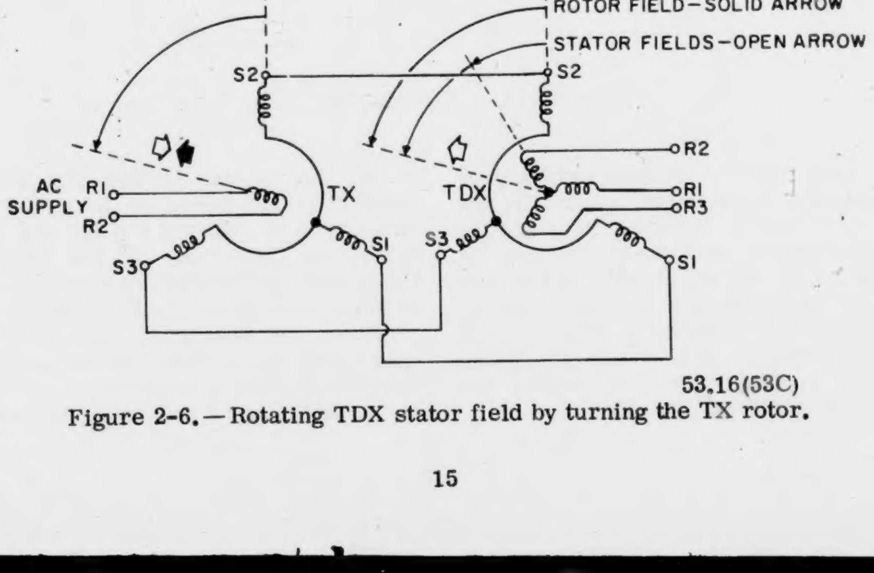
How the Differential Transmitter Adds

Frequently it is necessary to set up a TX-TDX-TR system for addition. This is done by reversing the S1 and S3 leads between the TX and TDX stators, and the R1 and R3 leads between the TDX rotor and the TR. With these connections the system behaves as illustrated in figure 2-8. The 75° and 30° mechanical inputs applied, respectively, to the rotor of the TX and the rotor of the TDX are added and transmitted to the TR whose rotor provides an output equal to their sum by turning to 105°.

NOTE: Adding or subtracting, as illustrated in figures 2-7 and 2-8 applies only when TDX rotor is turned in the same direction as TX rotor, since reversal of TDX or TX rotor direction will subtract when connected for addition, and vice versa. In principle, this applies also to TDRs, see figure 2-9 for examples.

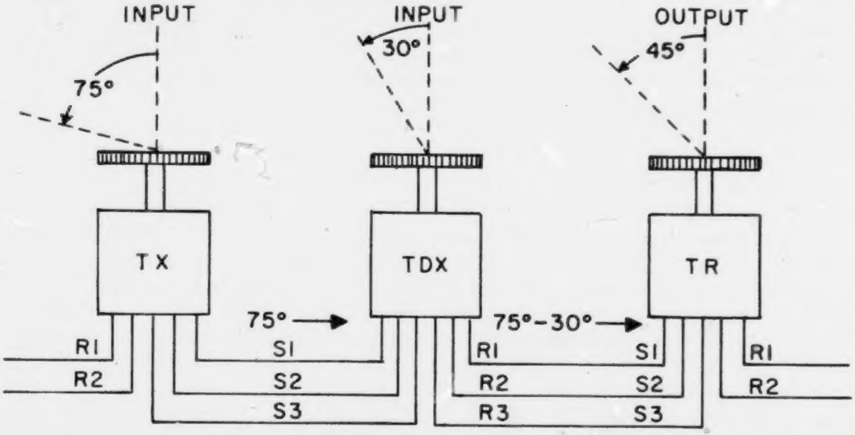
The Differential Receiver

The differential receiver's chief difference from the differential transmitter is its application. The TDX in each of the previous examples combined its own input with the signal from a synchro transmitter and transmitted the sum

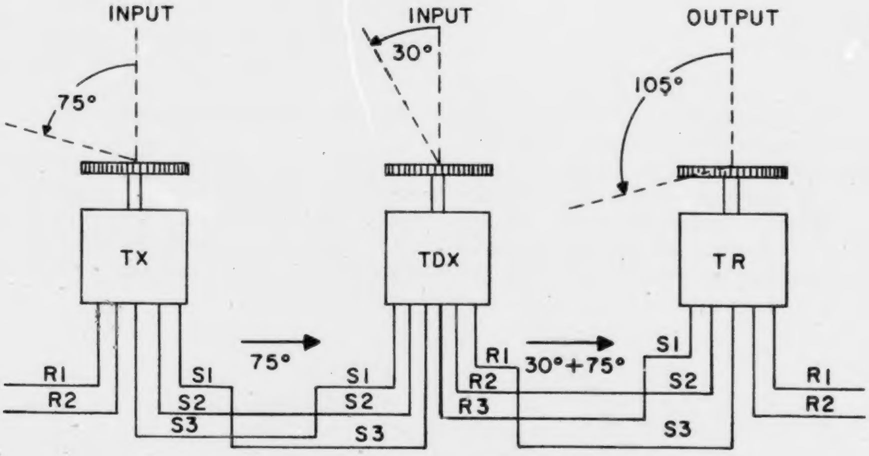


53.16(53C)

Figure 2-6.—Rotating TDX stator field by turning the TX rotor.


INPUT
75°
INPUT
30°
OUTPUT
45°
TX
TDX
TR
75°
75°-30°
R1
R2
S1
S2
S3
R1
R2
R3
S1
S2
S3
R1
R2

53.17(53C)
Figure 2-7.—Subtraction with TDX.

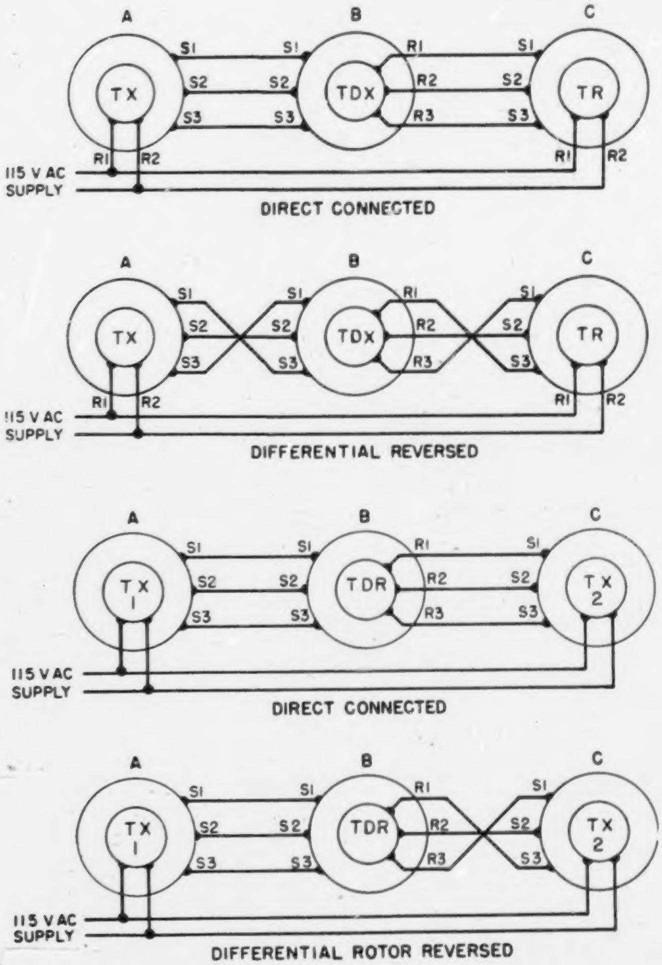

INPUT
75°
INPUT
30°
OUTPUT
105°
TX
TDX
TR
75°
30°+75°
R1
R2
S1
S2
S3
S1
S2
S3
R1
R2
R3
S1
S2
S3
R1
R2

53.18(53C)
Figure 2-8.—Addition with TDX.

or difference to a synchro receiver, which provided the system's mechanical output. In the case of the differential receiver in a torque system, the differential unit itself provides the system's mechanical output, usually as the sum or difference of the electrical signals received from two synchro transmitters. Figure 2-10 illustrates this operation in a system consisting of two TXs and a TDR (torque differential receiver) interconnected for subtraction.

To set up the system just considered for addition of the inputs of the two TXs, it is only necessary to reverse the R1 and R3 leads between the TDR rotor and the TX to which it is connected. With these connections reversed, the system operates as shown in figure 2-11.

Refer to Synchros, MIL-HDBK-225(AS) to understand more about how the addition and subtraction results are accomplished in differential transmitters and differential receivers.



1. Sum of inputs A & B if in opposite directions, C turning in same direction as A.

2. Difference between inputs A & B, if in same direction, C turning in same direction as A.

Same as Figure 2–7

1. Sum of inputs A & B if in same direction, C turning in same direction as A.

2. Difference between inputs A & B if in opposite directions, C turning in same direction as A.

Same as Figure 2–8

1. If A & C turn in same direction, B will turn in reverse direction and indicate difference between A & C inputs.

2. If A & C turn in opposite directions, B will turn in same direction as A and indicate sum of A & C inputs.

Same as Figure 2–10

1. If A & C turn in same direction, B will turn in same direction and indicate sum of A & C inputs.

2. If A & C turn in opposite directions, B will turn in same direction as C and indicate difference between A & C inputs.

Same as Figure 2–11

53.17-.20

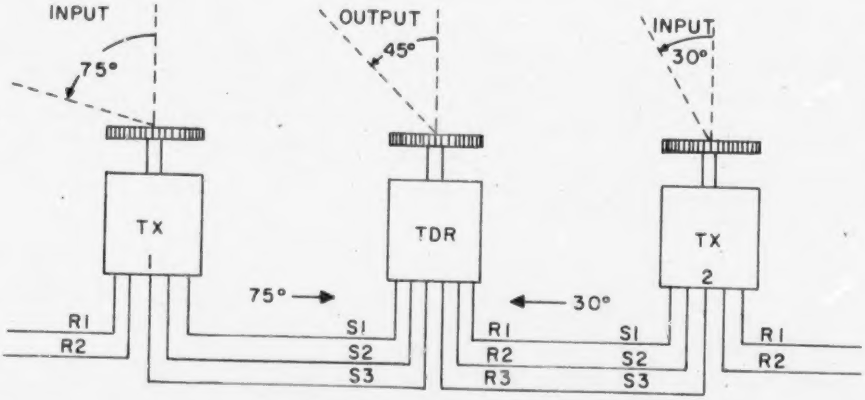
Figure 2-9.—Reversal of rotor direction.

FACTORS THAT AFFECT THE ACCURACY OF A TORQUE SYNCHROSYSTEM

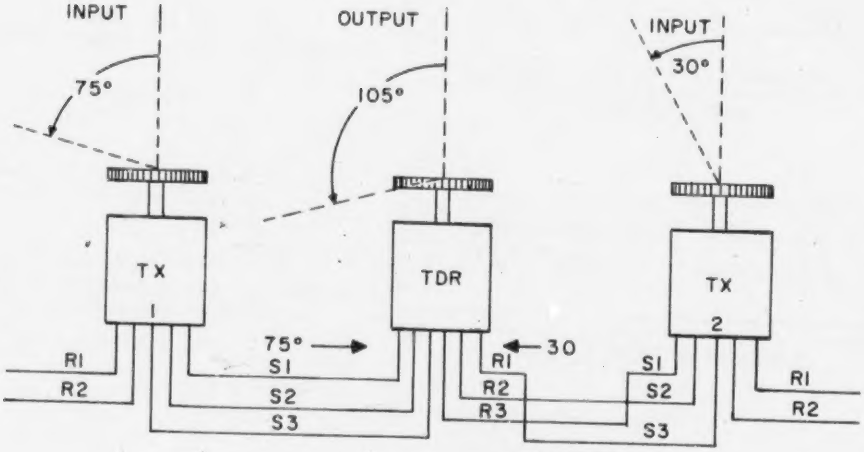
The accuracy of a synchrosystem is probably its most important characteristic. Torque system accuracy is determined by how closely the system's output shaft approaches the position indicated by the system's input or inputs. In such a system, perfect accuracy is never obtained. Regardless of how carefully receivers are constructed, electrical error and an error due to friction and load (called receiver error), are always present. A small but measurable amount of torque is required to overcome this friction; and when a receiver rotor is in perfect alignment with the signal applied to its stators, no torque is produced. The receiver lags slightly before producing enough torque to overcome brush and bearing friction and this lag is present as an error to any torque system.

Simple Torque Systems

In a torque receiver consisting of one transmitter and one receiver, two important factors


INPUT
75°
OUTPUT
45°
INPUT
30°
TX
1
TDR
TX
2
75° →
← 30°
R1
R2
S1
S2
S3
R1
R2
R3
S1
S2
S3
R1
R2

53.19(53C)
Figure 2-10.—Subtraction with TDR.


INPUT
75°
OUTPUT
105°
INPUT
30°
TX
1
TDR
TX
2
75° →
← 30
R1
R2
S1
S2
S3
R1
R2
R3
S1
S2
S3
R1
R2

53.20(53C)
Figure 2-11.—Addition with TDR.

must be considered to obtain maximum accuracy: (1) the friction on the shaft of the receiver must be reduced to an absolute minimum; and (2) the torque gradient of the receiver must be relatively high with respect to its combined friction and load, so that a very small lag produces sufficient torque to overcome both.

To satisfy these requirements, the ball bearings used on synchro receivers are selected with extreme care and are factory-lubricated according to strict military specifications. Also, both the transmitter and receiver must be large enough and have sufficient torque gradient to meet the needs of the system.

Torque Systems Involving a Number of Receivers

In a torque system where either a TX or TDX drives several receivers, the accuracy with which each receiver follows the position-data signal applied to its stators is determined by the following factors.

1. The friction and load on the shaft of that receiver.

2. The friction and loads on the shafts of all the other receivers. If any one of the receivers is excessively loaded, or if it becomes jammed the accuracy of the whole system is affected.

3. The torque gradient of each receiver is related to the number and size of the receivers being driven by the transmitter. If too many receivers are connected to a particular transmitter, its output voltages are reduced and an excessive overall lag is produced in the system.

One Transmitter With Many Receivers

One large synchro transmitter may be used to drive a number of small synchro receivers connected in parallel, if the impedance of the transmitter stator windings is low enough to supply the current necessary to activate all the receivers without excessive voltage drop.

If one synchro receiver has to supply more torque than the others, its shaft will lag further behind the transmitter's, producing less opposing voltage in its stator coils, and therefore it draws more current than other receivers. This increased current will lower the synchro transmitter's output voltage, causing the other receivers to lag more than before. For accuracy, it is essential that the synchro transmitter have low impedance (a high Unit Torque Gradient), and that the load on each synchro receiver be as low as possible. Equal loads are important. In the multiple system, any unnecessary load on any one synchro receiver affects the accuracy of the entire system. Using a box diagram and symbols, we show the action in figure 2-12.

We can appreciate the advantage of a synchrosystem when we consider that the moment a signal is fed into the synchro transmitter, this data is immediately and simultaneously transmitted to all receiver stations, regardless of how remote or isolated each may be from the others on shipboard. Another advantage, from the military standpoint, is that the knocking out of a receiver station will not interfere with the operation of the remaining units of the system.

ORDNANCE APPLICATIONS OF TORQUE SYNCHROSYSTEMS

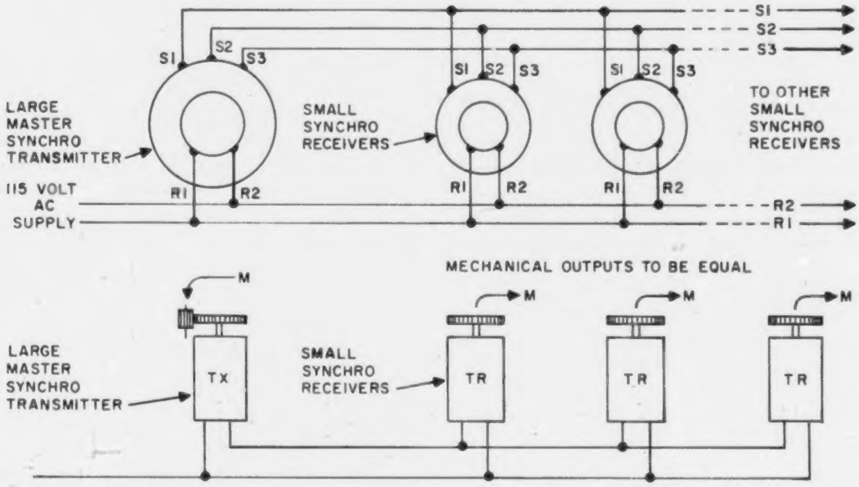
Torque synchrosystems are widely used in modern naval ordnance. In the familiar 5"/38 gun mount, gun train and elevation orders are relayed to the mount via a torque synchrosystem. In automatic control, torque-type synchros receive the gun order signals from a director or plot and, by mechanically positioning a fine pilot valve, control the mount's power drive. In local control, a "follow-the-pointer" system is used in which the pointer and trainer control mount movement with their handwheels and follow train and elevation orders as indicated on their dials. A similar indicating system is employed to transmit sight-setting and fuze-setting orders to the mount—all using torque synchrosystems. Down in plot, own ship's course and speed are transmitted to the Mk 1A computer from the ship's gyro and pitometer log by means of a torque synchrosystem. Although torque synchrosystems have many varied uses, they are principally used for indicating or data transmission purposes because of their inability to position with any accuracy anything but very light loads.

An example of the use of a synchro team using a TDR, TX and a TR, is found in star shell fire. Gun elevation is computed and the data mechanically cranked into the TDR as star shell elevation order. Star shell spots are corrected by mechanical inputs to the TX, figure 2-13. The corrected signal is sent to the TDR by the TX whose values make up the elevation gun order signal sent to the TR at the gun as elevation star shell position orders.

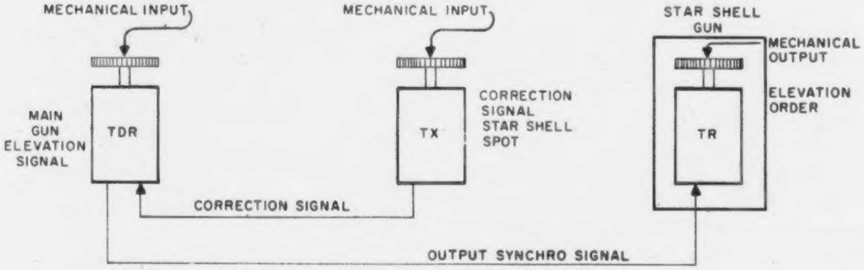
CONTROL SYNCHROSYSTEMS

The comparatively small mechanical output of a torque synchrosystem is suitable only for very light loads; and even when not heavily loaded, a torque system is never entirely accurate. The receiver rotor requires a slight amount of torque to overcome its static friction, and this torque can only be produced by a small error in the system. Torque systems place a drag on associated equipment, which affects their accuracy.

When larger amounts of torque, or a higher degree of accuracy, or both, are required, torque synchrosystems give way to control synchros used as components of servosystems. Synchros control the servosystem; the servos provide the torque or power.


S1
S2
S3
LARGE MASTER SYNCHRO TRANSMITTER
SMALL SYNCHRO RECEIVERS
S1
S2
S3
TO OTHER SMALL SYNCHRO RECEIVERS
115 VOLT AC SUPPLY
R1
R2
R2
R1
MECHANICAL OUTPUTS TO BE EQUAL
M
LARGE MASTER SYNCHRO TRANSMITTER
TX
SMALL SYNCHRO RECEIVERS
TR
TR
TR

53.256
Figure 2-12.—One transmitter, many receivers.


MECHANICAL INPUT
MECHANICAL INPUT
STAR SHELL GUN
MECHANICAL OUTPUT
ELEVATION ORDER
MAIN GUN ELEVATION SIGNAL
TDR
TX
CORRECTION SIGNAL STAR SHELL SPOT
TR
CORRECTION SIGNAL
OUTPUT SYNCHRO SIGNAL

53.257
Figure 2-13.—Star shell fire.

THE CONTROL TRANSFORMER

The distinguishing unit of any synchro control system is the control transformer (CT). The CT is a synchro designed to supply, from its rotor terminals, an a.c. voltage with magnitude and phase dependent on its rotor position and on the signal applied to the three stator windings. It is similar to a TX or TR (which actually can operate as a CT) but is designed for optimum performance as a control device. The behavior of the CT in a system differs from that of the synchro units previously considered in several important respects.

The stator windings of a CT are connected to and receive power from a transmitter or differential transmitter. The rotor winding acts only as the secondary of a transformer and is never connected to a voltage source. The rotor itself is a slotted symmetrical drum and its position has no effect on the stator currents. Also there is never an appreciable current flowing in the rotor winding because its output voltage is always applied to a high impedance load, 10,000 ohms or more. Therefore the rotor does not turn to any particular position when voltages are applied to the stator windings. The rotor shaft of a CT is always turned by an external force (usually by the servomotor which is being controlled), and produces varying output voltages from its rotor windings. Like synchro transmitters, the CT requires no inertia damper;

but unlike either transmitters or receivers, rotor coupling to S2 is minimum when the CT is at electrical zero.

Relationship of Stator Voltages to the Resultant Magnetic Field

When current flows in the stator circuits of a CT, a resultant magnetic field is produced. This resultant field can be rotated by the signal from a synchro transmitter or synchro differential transmitter in the same manner as the resultant stator field of the TDX previously considered. When the resultant field of the CT stator is at right angles to the magnetic axis of the rotor winding, the voltage induced in the rotor winding is zero. When the resultant field and the rotor winding magnetic axes are aligned; the induced rotor winding voltage is maximum. Since no opposing voltages are induced in the stator of the CT, the effective strength of the resultant field is constant, regardless of its position. The strengths of the individual fields which make it up, however, vary with the current in the individual stator coils, and therefore with the individual stator voltages. This means that the phase and magnitude of the stator voltages determine the direction of the resultant magnetic field. Since the CT's output is expressed in volts, it is convenient to consider its operation in terms of stator voltages as well as in terms of the position of the resultant magnetic field, but it should be remembered that it is the angular position of this fluctuating magnetic field with respect to the rotor axis that determines the output of the CT.

The Role of the CT

Assume a synchro team is required to train a gun and that a synchro transmitter will be used with a synchro control transformer for this purpose (fig. 2-14). The synchro transmitter rotor receives power from the AC supply. The operator will crank in, as a mechanical input, a particular setting. This will cause the synchro transmitter stator to transmit a specific primary voltage to the synchro control transformer stator and, in turn, induce secondary voltage in the rotor winding of the synchro control transformer. This secondary voltage, transmitted over leads R1 and R2, is used by the power amplifier to control the operation of the drive motor for the training of the gun. The gun mount, in turn, is geared to the rotor of the synchro control transformer to provide the mechanical response. When the rotor of the synchro control transformer has been turned by response to an amount equal to the signal from the synchro transmitter, the output voltage from the synchro control transformer drops to zero, and the signal to the amplifier ceases. This causes the power motor to cease operation. Thus the gun has been trained to correspond to the original signal cranked into the system. The synchro control transformer rotor is brought into correspondence within a fraction of a second after mechanical input to the synchro transmitter stops.

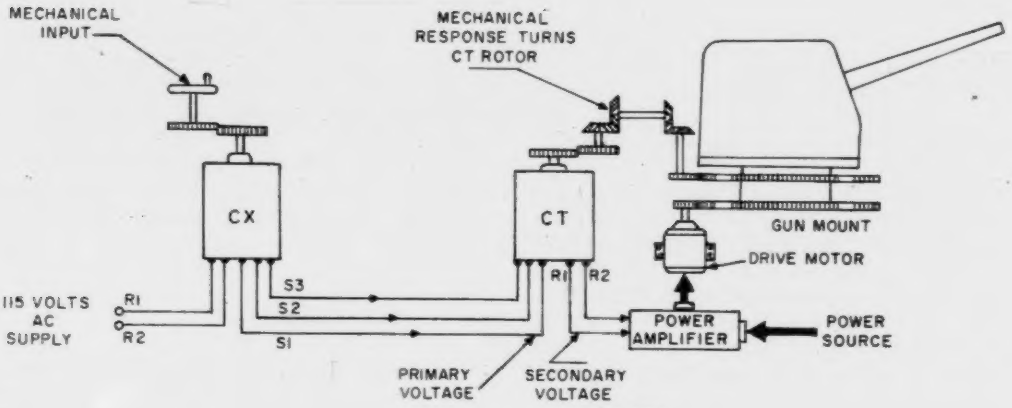
Operation With a Synchro Transmitter

Consider the conditions existing in the system shown in figure 2-15, where a CT is connected for operation with a CX (control transmitter) and the rotors of both units are positioned at 0 degree. The relative phase of the individual stator voltages with respect to the R1 to R2 voltage of the transmitter are indicated by small arrows. The resultant stator field of the CT is shown in the same manner as for the TDX. With both rotors in the same position, the CT stator field is at right angles to the magnetic axis of the rotor coil. Since no voltage is induced in a coil by an alternating magnetic field perpendicular to its axis, the output voltage appearing across the rotor terminals of the CT is zero.

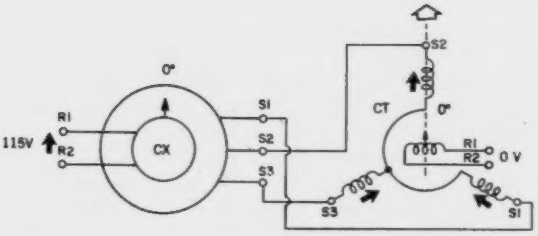
Now assume that the CT rotor is turned to 90° (fig. 2-16) while the CX rotor remains at 0 degree. Since the CT's rotor position does not affect stator field of the CT remains aligned with S2. The axis of the rotor coil is now in alignment with the stator field. Maximum voltage, approximately 55 volts, is induced in the coil and appears across the rotor terminals as the output of the CT.

Next, assume the CX rotor is turned to 180° (fig. 2-17). The electrical positions of the CX and CT are 90° apart, the CT stator field and rotor axes are aligned, and the CT's output is again maximum, but the direction of the rotor's windings is now reversed with respect to the direction of the stator field. The phase of the output voltage is therefore opposite to that of the CT in the preceding example. This means that the phase of the CT's output voltage indicates the direction in which the CT rotor is displaced with respect to the position-data signal applied to its stators.

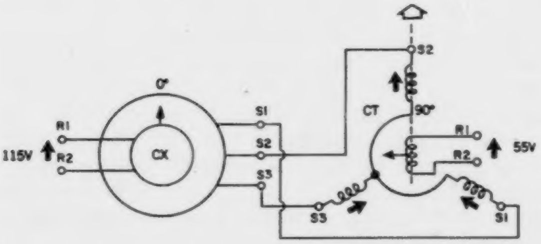
It is evident that the CT's output can be varied by rotating either its rotor or the position-data signal applied to its stators. It can also


MECHANICAL INPUT
MECHANICAL RESPONSE TURNS CT ROTOR
CX
CT
GUN MOUNT
DRIVE MOTOR
115 VOLTS AC SUPPLY
R1
R2
S3
S2
S1
R1
R2
POWER AMPLIFIER
POWER SOURCE
PRIMARY VOLTAGE
SECONDARY VOLTAGE

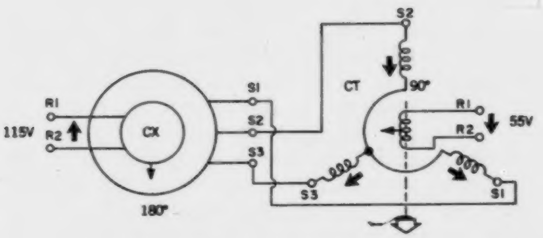
53.258
Figure 2-14.—Synchro team.


0°
R1
115V
R2
CX
S1
S2
S3
CT
S2
0°
R1
R2
0 V
S3
S1

53.21
Figure 2-15.—Conditions in CX-CT system with rotors in correspondence.


0°
R1
115V
R2
CX
S1
S2
S3
CT
S2
90°
R1
R2
55V
S3
S1

53.22
Figure 2-16.—Conditions in CX-CT system with CX rotor at 0° and CT rotor at 90°.

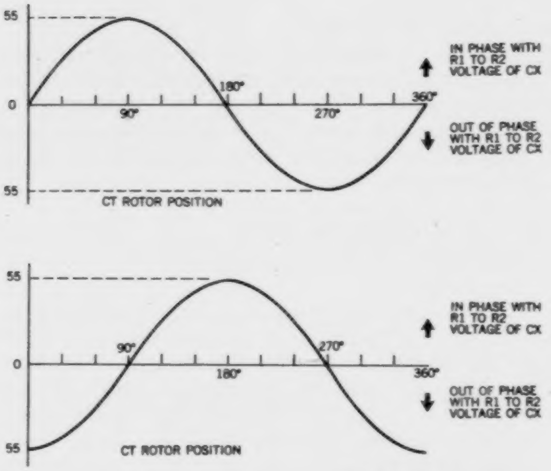

R1
115V
R2
CX
180°
S1
S2
S3
CT
S2
90°
R1
R2
55V
S3
S1

53.23
Figure 2-17.—Conditions in CX-CT system with CX rotor at 180° and CT rotor at 90°.

be seen that the magnitude and phase of the output depends on the relationship between signal and rotor rather than on the actual position of either. The graphs in figure 2-18 illustrate the difference in the CT output when the CT rotor is first rotated through 360° with the CX rotor at 0°, and with the CX rotor at 90 degrees.

Turning CX Rotor

The turning of the CX rotor causes four things to happen in the CT: (1) The magnetic fields in the CX and the CT are caused to rotate; (2) voltages are induced in the CT's rotor; (3) polarity of the CT's rotor leads, with respect to voltage energizing the CX's rotor becomes established;



12.165(53A)
Figure 2-18.—CT output voltage.

and (4) response gearing rotates the CT's rotor toward the position of correspondence.

The important points to remember about the operation of a CT are: (1) when the CT's rotor is in the same electrical position as the position-data signal applied to its stator, that is, in the same position as the resultant stator field, the electrical output of the unit is zero; (2) when displacement with respect to each other is less than 90°, any change in the angular relationship between the rotor and the position-data signal produces a corresponding change in the magnitude of the CT's output; and (3) the direction of CT rotor displacement with respect to the position-data signal is always indicated by the phase of the CT's output voltage.

As indicated in figure 2-18 the electrical output of the CT is always zero when the rotor is displaced with respect to the position-data signal by 180 degrees. It is therefore necessary to identify the CT rotor position at which 0 volt indicated agreement with the signal. In the case of the simple CX-CT combination, this is done by the phases of the two rotor voltages. If the CX and CT rotors are in the same position, the CT rotor voltage is zero; turning the rotor slightly counterclockwise from the "0 volts" position produces a voltage from R1 to R2 on the CT that is in phase with the voltage from R1 to R2 on the CX.

In practical applications of the CT, its rotor is positioned for proper operation in a particular system by one of the zeroing procedures described in GMG 3/2. Consideration of the servosystems (discussed in following sections of this chapter) also shows that a 180° displacement of the CT rotor can usually be detected in the behavior of the system's output.

ERRORS IN CONTROL SYNCHROSYSTEMS

Three factors which produce errors in control systems are electrical error, errors inherent in control transformers, and errors resulting from the use of torque and control units in the same system.

Electrical Error

The difference between the actual physical position and the electrical position of a synchro is known as electrical error. Consider a control system consisting of a control transmitter and a control transformer. If the CX and CT each have an electrical error of 12 minutes, the total possible error is 24 minutes. Adding a control differential transmitter having an electrical error for rotor and stator of 10 minutes each to this system, the total error increases to a possible 44 minutes or about 3/4 of a degree. The effect of such an error depends on the use of the particular system. In a gun training system, a 1/2° or 1° error becomes more pronounced at increased distances. The fact that synchro transmitters, differential transmitters, and control transformers are driven does not make them free from electrical errors. Manufacturing irregularities in the windings and the magnetic structure are inherent in all synchros.

Errors of Control Transformers

In a simple CX-CT system, it usually is assumed that the null position for the CT rotor always occurs when the axis of the CX and CT rotors are at 90° displacement; however, this is seldom true. As an example, if a CX and CT are so positioned that the CT output is minimum and then the CX rotor is turned exactly 15°, the CT rotor usually must be turned slightly more or less than 15° to again obtain a null reading. Note that a null or minimum reading, rather than a zero reading, has been specified. The voltage output of a CT never becomes zero, but generally, at correspondence, falls as low as 50 to 125 millivolts for 115-volt synchros. Also, the null voltage obtained varies as the CX rotor position is varied. It is usual practice in a servo for the system to operate in such a manner that the CT output is a null. It should be obvious, therefore, that any variation in the position at which a null is obtained is reflected as an error in the entire system. Corrective measures also must be taken to compensate for phase shift in a servo. The impedance of the synchro windings causes the CT voltage to lead the CX supply voltage.

In a system where more than one control transformer is used, if the drive to one of the control transformers is inoperative, that CT may introduce error into the system which increases as the angle between its correct and actual position increases.

When control transformers are rotated at high speeds, an additional error (known as speed error) may be introduced. The null voltage position of the control transformer no longer occurs when the CT rotates at synchronous speed with the transmitter, but occurs when the CT rotor is at an angle to its correct synchronous position. The angle depends upon the speed of rotation, and usually lags behind that obtained under static conditions. As the number of CT's in a system increases, the speed error is apt to increase. Also, the speed error for a given speed is comparatively larger for a smaller size transmitter. However, speed error is usually negligible until approaching synchronous speed for the excitation frequency involved. For the usual two-pair synchros this is approximately 2800 rpm for 60-Hz and 19000 rpm for 400-Hz. Considering CTs of the same size and rotating at the same speed, the speed error is therefore considerably less for 400-Hz units than for 60-Hz units. When necessary devices are used to compensate for speed error.

Use of Torque and Control Units in Same System

Many systems use both torque and control units; however, the use of torque units in a control system is usually avoided where accuracy is of prime importance.

In addition to electrical error, TRs and TDRs are subject to receiver error, difference between position assumed by TR or TDR, and position transmitted by TX, which often is as great as 1°. Receiver error, also called position error, is caused by brush and bearing friction and actual receiver load. Any increase in friction or load on a TR or TDR, or adding more TRs or TDRs to the system, increases the resultant bus error. Smaller receivers have such a low torque gradient value that, as lubrication deteriorates with use and bearings become dirty, the receiver error increases. Receivers also are subject to oscillations, and irregular or excessive oscillations are reflected as an additional bus error. When torque and control units are used in the same system, excitation must be supplied by a torque transmitter rather than a control transmitter.

ORDNANCE APPLICATIONS OF CONTROL SYNCHROSYSTEMS

Control synchrosystems are, as previously stated, usually part of a larger system called a servosystem. A familiar example of such a system is the Mk 35 amplidyne power drive which is used in the twin 3''/50 gun mount. This drive system will be described in the next two chapters of this course. Other amplidyne drive systems using control synchros are those of the GMLS Mk 25 Mod 0, and of the Mk 39 5''/54 gun mount.

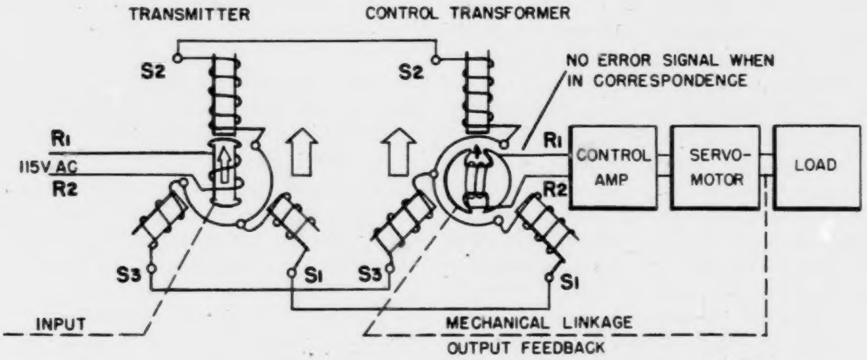
Control synchros are also used in the receiver-regulators for the Mk 16 ASROC Launcher, which you read about in GMG 3/2, and in the receiver-regulators for the Mk 42 5''/54 gun mount. The control equipment for the 5''/54 gun mount, Mk 42, will be briefly described in chapter 6 of this course.

Synchro control transformers are often used as error detectors in a servomechanism system which may be used to control the movement of a gun mount, a small indicator motor, or many other such loads (fig 2-19). More information on servomechanisms and servosystems (which are much the same thing) will follow in this chapter.

SERVOMECHANISMS AND SERVOSYSTEMS

Electrical arrangements that cause mechanical action to take place automatically in response to synchro signals are called followups or servomechanisms. A servomotor is one of the components of a followup. A servomotor is a reversible motor that operates in a slave-to-master relationship with the synchro equipment from which it receives its input signals. There are both a.c. and d.c. types of servomotors. The servomotor used in amplidyne power drives is a d.c. type. Certain dials and mechanisms in computing equipment are turned by a.c. types.

Figure 2-19 illustrates the elements of a servosystem. The functioning of such a system



53.259

Figure 2-19.—The control transformer as an error detector.

is described below with reference to how its principle is utilized in positioning a gun.

1. At a remote station, all available information about the target is collected and combined. To the gun mount is transmitted a pair of order signals telling, respectively, what values of train and elevation will put the gun in firing position.

2. The order signal is compared with the actual position of the gun. The result of this comparison is a command (called the error signal) telling how far and in which direction the gun must move.

3. When properly amplified, the error signal operates the controls of a power drive.

4. The power drive moves the load in such a way as to reduce the error.

5. While the load is being driven, a response signal is sent back continuously and automatically for comparison with the order signal.

6. When the two error signals (train and elevation) have been reduced to zero, the gun is in the ordered position for firing.

SERVO PRINCIPLES

Now consider how the servo principle is applied in a typical servomechanism or "followup" using an a.c. reference voltage. Compare figures 2-19 and 2-14. In figure 2-14 the parts in the mechanism corresponding to the diagram of figure 2-19 are a synchro control transformer which serves as the signal receiver and comparison device, an electronic amplifier and a.c. servomotor which together correspond to the power drive, and gearing from the motor which drives the load and the synchro control transformer rotor. The amplifier may be of the tube, magnetic, or transistor type, or a combination. The load may be a dial, a computing device, a hydraulic valve, a synchro transmitter, etc. We omit a number of components used in many systems to improve the stability and response of the servo, such as damping generators, amplifier feedback and stabilizing circuits, discrimination circuits which automatically select the appropriate input signal, capacitors for improving electrical characteristics and for changing phase relationships, etc.

The input that starts the servomotor is the output voltage of the synchro control transformer. This voltage has to be amplified before it can be used. As the servomotor turns, in response to the input voltage, the rotor shaft furnishes a mechanical output to the gearing that turns the load.

The load in figure 2-14 is connected back, through gearing, to the rotor of the synchro control transformer. The result of this mechanical feedback is to drive the rotor in such a direction as to reduce the electrical output of the control transformer. When the load reaches the position originally ordered, the output of the control transformer becomes zero, and the motor stops.

The example chosen is a common type of servomechanism, but many other varieties and combinations of components are possible. It is possible to use a mechanical differential, an electrical resolver, a synchro differential transformer, a special type of movable-core transformer, or any of several other devices for the error-sensing unit. The variety possible in amplifiers has already been mentioned, as well as in auxiliary circuits and devices. Several kinds of motors are available, and so on. But the servo principle underlies all these combinations.

The output drive motor in a servosystem should have the required power, be easily reversible, and be capable of speed control over a fairly wide range. Ordinarily, an a.c. motor cannot fulfill the requirements of a servo drive motor as completely as a d.c. motor because the range of speed control is less. However, the use of an a.c. motor may provide a much simpler drive system, especially where a.c. power is the only source available and where some sacrifice in range of speed control can be made.

SERVO TERMINOLOGY

Before going on into the larger and more elaborate servosystems, we should become more familiar with some of the specialized terms that are used in connection with servosystems. The more common of these are defined here.

OPEN-CYCLE CONTROL of a servosystem means actuation of the servo solely by means of the input data, the feedback device being either removed or disabled. It should be clearly understood here that any mechanism must include a feedback provision in order to be classified as a servo; but in testing certain servo characteristics, an open-cycle control is often useful. Under such conditions the elements involved are frequently referred to as an open servoloop.

CLOSED-CYCLE CONTROL refers to normal actuation of the system by the difference between input and output data, with the feedback device operative.

CONTINUOUS CONTROL is used to describe uninterrupted operation of the servosystem on its load, regardless of the smallness of the error. All systems considered in this book exercise continuous control; however, there are systems which do not.

DEVIATION or error of a servo, is the difference between input and output.

ERROR SIGNAL or error voltage is the corrective signal developed in the system by a difference between input and output.

INSTRUMENT SERVOS and POWER SERVOS are designations used to classify servomechanisms according to their power output. An instrument servo is one rated at less than 100 watts maximum continuous output; a servo whose rating exceeds this amount is a power servo.

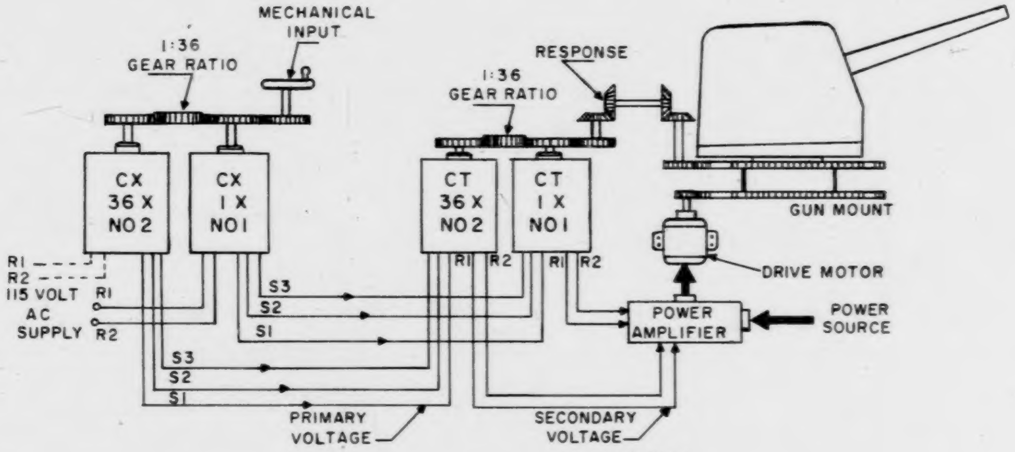
DUAL-SPEED SYSTEM

The one-speed system, described so far in this chapter, is geared so that one-degree movement of the mount or gun is equal to one-degree movement of the synchro control transformer (CT). This system is used for getting the mount or gun into approximate correspondence with the position order signal. It does not, however, provide the required accuracy at the point of correspondence.

To obtain better control of a mount or gun system, two synchros are used, 1-speed (1X) for coarse control and 36-speed (36X) for fine control. For simplicity, the two systems are referred to as the 1X and 36X synchros. Only one synchro output is used at any one time. The 1X synchro is used when the position error signal is greater than 2 degrees. The 36X synchro is used when the position error signal is less than 2°. Synchro selection (change over) takes place in the servo amplifier or receiver regulator, depending on the type of power drive used. Most dual speed synchro systems are designed so that synchro change over from the coarse CT to the fine CT takes place within 2.5° of synchronization, but can differ depending on the type of gun system. Synchro change over can accure at 2°, 2 1/2° or 3° of synchronization. Both the 1X and 36X CTs are geared to the response mechanism from the gun or mount.

If the 1X synchro is rotated 90°, the synchro is equivalent to 90° of rotation of the mount, as shown in the schematic of a dual-speed system (fig. 2-20). In the 36X system, however, a rotation of 90° of the 36X synchro is equal to only 2 1/2° of mount rotation.

A basic dual-speed synchrosystem consists of two transmitters (CX) and two receivers (CT). One CX receives the external input to the system and, through a network of gears, passes the effects of the external input to the second transmitter (CX) (fig. 2-20). The gear ratio between the two CXs determines the two specific speeds which the system will use to transmit the input data. If, for example, the gear ratio between the two CXs is 1:36, one revolution of the rotor of the first CX causes 36 revolutions of the rotor of the second CX. Thus, the first transmitter (the one which accepts the external input) is called the coarse CX, and the second one is called the fine CX. The outputs of each CX are passed through standard synchro connections



53.260
Figure 2-20.—Dual speed system.

to two CTs. One CT receives the coarse signal and the other receives the fine signal. The two CTs are connected by gears similar to the ones between the two CXs. For continuously accurate operation, CT gearing is essential.

In a 1X and 36X synchrosystem, one revolution of the rotor of the coarse CX causes 36 revolutions of the rotor of the fine CX. While the rotor of the coarse unit makes one revolution, it passes its 0° reference or synchronization point only once. Meanwhile, however, the rotor of the fine unit passes its synchronization point 36 times. The significance of this latter statement is that the fine CT has 36 synchronization points. Only one of these apparent points, however, can be the true synchronization point.

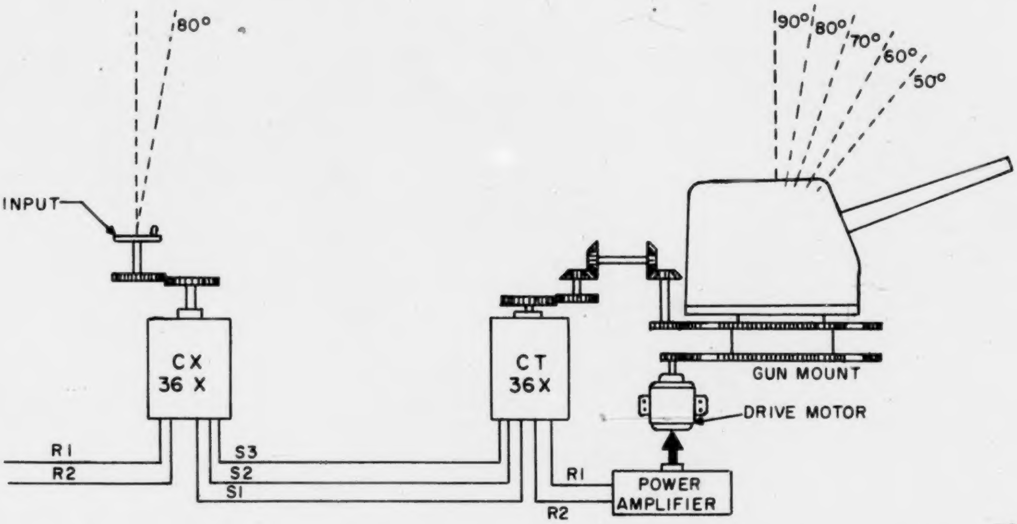
If, while the synchrosystem is deenergized, the rotor of the fine CT is moved one complete revolution but the rotor of the coarse CT is not moved, the output of the fine CT would be in error when power is restored. To prevent this possibility, gearing is placed between the two CTs. Hence, the rotor of one CT mechanically follows the movement of the other. Therefore, this gearing is one method of removing the synchronization uncertainties of the fine CT and, in turn, from the system. The transmission of torque-type and control-type two-speed synchrosystems is geared the same way.

The receiver of a control-type servosystem is a CT. Because the rotor of a CT is not energized, the error voltage induced into the rotor can be zero at two positions, the correct 0° reference position, and 180° from the correct position. This feature complicates the problem of false synchronization by doubling the number of apparent synchronization points. This problem is corrected by adding a stick-off voltage in series with the CT rotor circuit. A discussion of this corrective measure is detailed in chapter 6 of this text.

Disadvantages of Dual Synchrosystems

The main disadvantage of the 1X and 36X synchrosystem is that the servosystem is no longer self-synchronous. In the one-speed synchrosystem the output shaft is synchronized with the input shaft at only one point. In other words, there is only one position that the output shaft can assume which will allow correspondence between the rotors of the CT and the CX. We know that in the 36X system, however, the CT can be in correspondence at 36 different positions for any one position of the input shaft of the CX. For example, if the rotor of the CX is at 80° (fig. 2-21), the output shaft and consequently the gun or mount could be synchronized at 90°, 80°, 70°, and so on, in steps of 10°. In each of these positions of the CTs rotor, the position of the CT is stepped up 36 times so that it is an integral multiple of 360°, thus bringing the CT into false correspondence with the CX in each case.

Because of this, the fine synchrosystem is never used by itself, since, as you have seen,



53.261
Figure 2-21.—Fine synchro system can cause gun to synchronize at any multiple of 10 degrees.

it does not provide true synchronization of its input and output at all times. We certainly do not want a gun pointed at 60° when the CX is positioned at 80°. Therefore, the fine system is always combined with a coarse system. The fine synchrosystem provides a very sensitive control at times when the error between the order signal and the servo output is small. Since this is a 36X synchro, however, it can bring the gun to any one of 36 positions. It is the job of the coarse synchrosystem to bring the gun mount close enough to the true synchronous position so that it is within the range of the fine synchro.

Therefore, you must have some way for the coarse synchro to take control and drive the launcher into correspondence whenever the error exceeds a certain amount—in most cases about 2°. The circuits that accomplish this have many names. Some of these are:

1. Synchro changeover circuit
2. Synchro crossover network
3. Synchronizing circuit

The switching elements used in these circuits could be relays, transistors, or electron tubes. How these circuits function to accomplish synchro changeover is explained in chapters 3 and 6 of this text.

PERFORMANCE OF SERVOSYSTEMS

A servosystem must operate smoothly, rapidly, and with as few errors as possible. The motion and position of the servosystem's output should duplicate the motion and position of the input. We do not get an ideal performance from servosystems because they do not react immediately to a change in order signal. The output will always lag the input. Any action of the output of a servosystem, regardless of what it is, requires time to take place. The output of a servosystem (which could be electrical, mechanical, hydraulic or any combination of these) requires a reaction time, which causes the output to lag behind the order signal; the order signal causes a servosystem to function. Any lost motion in mechanical linkages or gearing will produce a delay. In hydraulic units, the expansion and contraction or the heating up of hydraulic fluids causes a lag to the flow of hydraulic fluids through hydraulic lines and slows the movement of hydraulic pistons and valves. In the electrical section of a servosystem the elements between the input device and the output device, such as transformers, filter capacitors and electrical or electronic couplings contribute somewhat to the time difference between the input signal and the output motion.

One method of increasing the speed in which a servo answers an input signal is to increase the gain of the amplifier which serves the system. The gain in a servosystem is the ratio of change in output motion to a change in input voltage. The larger this ratio the higher the gain. The higher the gain the more sensitive the servo's output. If the gain of a servo is set too high, the output of the servo changes so rapidly it loses track of where the input order is, causing oscillation across the input signal. Oscillation or hunting is a very rapid back-and-forth movement of the output's load across the input signal, trying to "catch" the input. We can reduce the servo's tendency to oscillate by decreasing the gain of the amplifier. If we cut the gain down too far, the servo will overshoot the input signal due to not enough sensitivity. To prevent both oscillation and overshooting, servos are provided with devices that directly and indirectly control the gain of amplifiers. Let's explore the meaning of these two terms before continuing the study of servosystems.

Oscillating

Oscillating, frequently called hunting, occurs when the output drives back and forth across the ordered position in short rapid swings, as though the output device were looking for a place to stop but never finds it. Hunting is also characterized by its continuous action; it never stops or dies out; it can be very dangerous. If the output device oscillates at a rapid rate for a long time, it is possible to shake a gun mount or launcher to pieces and damage both the power drives which control them and the weapons within the equipment, such as ASROC missiles.

Overshooting

Overshooting is similar to hunting, but the movement of the output load dies out after a short period of time. Overshooting starts out as large over-travels and progressively get smaller until eventually the output shaft stops.

To get an idea of overshooting, we will look at how a servo reacts to a fixed input signal. Assume that the input shaft at the CX is stationary and at zero degrees, and the output shaft of the CT is at 10°. When the servo is energized, the servo motor will drive the load and try to reduce the error signal to zero when the desired position is reached. At which point the system is nulled and the error is zero. But, because the load and power drive have inertia and momentum, the output load continues driving beyond the desired position. When the load crosses the desired position, an error is generated in the opposite direction which tends to reverse the direction of the output load. However, it takes the error signal some time to bring the output load to a stop. In other words, because there are components in a servo that do not react immediately to a signal, some time elapses before the output load can reverse its direction. During the response lag time period the output load continues to move in the original direction, causing a larger error between the input and output. When the output load does stop, the error signal immediately starts to drive the output load back toward the desired ordered position. As the output load approaches the point of correspondence, it again has acquired enough speed in the reverse direction to again pass the ordered position. The result is a series of progressively smaller over-travels passed across the desired position until finally the output signal catches up with the ordered signal and the servosystem stops.

Reducing Overshooting

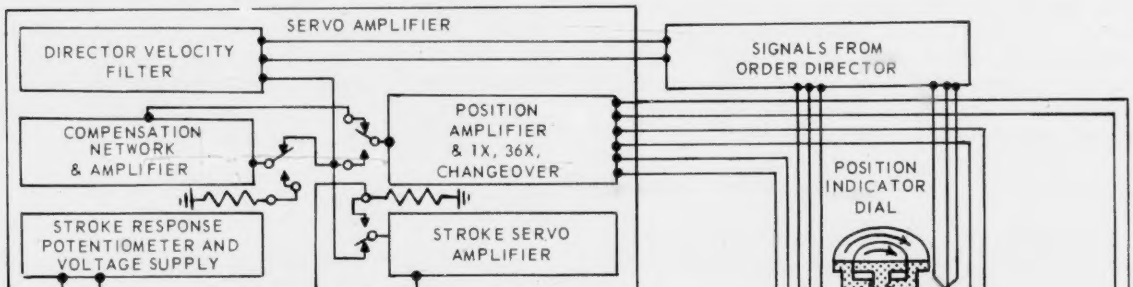
To reduce overshooting and hunting, servos are provided with damping devices or circuits. They are frequently called stabilizing or anti-hunt circuits, and usually use some form of feedback. Feedback, you remember from GMG 3/2, is the method by which a sample of the output is returned or fed back to the input to be added to or subtracted from the input, thereby changing and controlling the output.

The damping or stabilizing circuits in power servos are capable of acting as positive feedback devices to increase the gain of a servoamplifier when the error signal is increasing. It also acts as a negative feedback to reduce the gain of the amplifier when the error signal is decreasing. In this manner servos are prevented from overshooting and oscillating.

We will explain three of the many methods of reducing overshooting and hunting in power drive servos. One method which is the technique of using a CT with a movable stator to prevent a gun or mount from overshooting a fixed order signal is explained in chapter 13 of GMG 3/2, NP 10185-A. The other methods we will cover are the use of a tachometer generator for damping out oscillations and the integral control method, which increases the ability of a servo to follow slowly changing error signals and reduce velocity error.

Tachometer Generator

Feedback is commonly used to reduce overshooting and hunting. One method of providing feedback is to use a d. c. tachometer generator. This device is commonly called a "tach." It's application is shown in figure 2-22. The tach (GCT1) is geared to, and rotates with, the servo's output. The tach's output is a d. c. voltage whose amplitude is proportional to the output shaft speed. Also, the polarity of this voltage indicates the direction of the output rotation. The output of the tach represents the load velocity (rate). This velocity voltage is connected to the amplifier so that it opposes the error signal. Whenever the error signal changes, the rate feedback signal opposes any change in the error signal. In other words, the error signal is damped. The effect on the servo is as though you have increased the friction on the output shaft. This method of using a feedback signal proportional to the velocity of the output of a servo is also called velocity feedback. It is used in some gun and missile system power drive servos to prevent overshooting when the system is synchronizing to a fixed input order signal. Under these circumstances, gun mount velocity increases as it approaches synchronism


SERVO AMPLIFIER
DIRECTOR VELOCITY FILTER
SIGNALS FROM ORDER DIRECTOR
COMPENSATION NETWORK & AMPLIFIER
POSITION AMPLIFIER & 1X, 36X, CHANGEOVER
POSITION INDICATOR DIAL
STROKE RESPONSE POTENTIOMETER AND VOLTAGE SUPPLY
STROKE SERVO AMPLIFIER
RAT1
POTENTIOMETER
36X
1X
36X
1X
GCT3
GCT2
A-END RESPONSE LEVER
1X
A END
CAB
UNIT
B END
RAT3
RAT4
36X
36X
36X
TACH GCT1
B-END VELOCITY TO TEST CIRCUIT
B-END RESPONSE

53.262

Figure 2-22. — Feed back method to reduce overshooting and hunting.

and, therefore, the effect of velocity feedback is to slow down the gun mount before it approaches the ordered position.

Using A Potentiometer

Figure 2-22 also shows another method of using velocity feedback to prevent overshooting. Instead of a tach, a potentiomenter (RAT-1), whose sleding arm is connected to the A-end stroke mechanism, provides a velocity signal which opposes any change in the position error signal. Since the direction and amount of A-end tilt is a close approximation of gun mount velocity, a pot can be used in place of a tach to get the same damping effect. Both methods produce the same result, they slow down the load before it reaches synchronism.

Velocity Signal

The voltage output from the stroke response potentiometer (SRP) is applied to the servo amplifier and is compared with the input signal. The algebraic sum of these two voltages controls the gun's power drive output. When the gun is in motion, three possibilities exist: (1) the output of RAT-1 is equal to the reference voltage (constant velocity); (2) the output of RAT-1 is less than the reference voltage (acceleration); and, (3) the output of RAT-1 is more than the reference voltage (deceleration).

CONSTANT VELOCITY.—When the gun is traveling at proper speed in response to its command signal, it has a constant velocity. Therefore, no change in acceleration is required. Under these conditions the output of RAT-1 (figure 2-22) is equal to the reference voltage but is opposite in polarity and the resultant output is zero.

ACCELERATION.—When the gun is moving slower than the ordered velocity, the voltage at RAT-1 is less than the reference voltage. The output of the servo amplifier operates the control unit of the power drive to increase its output and accelerate the gun.

DECELERATION.—When the gun is moving faster than the ordered velocity, the voltage at RAT-1 is greater than the reference voltage. The output of the servo amplifier reverses current flow to the control unit and moves it in the opposite direction, causing deceleration of the mount. The output of the SRP is negative for increasing orders and positive for decreasing orders.

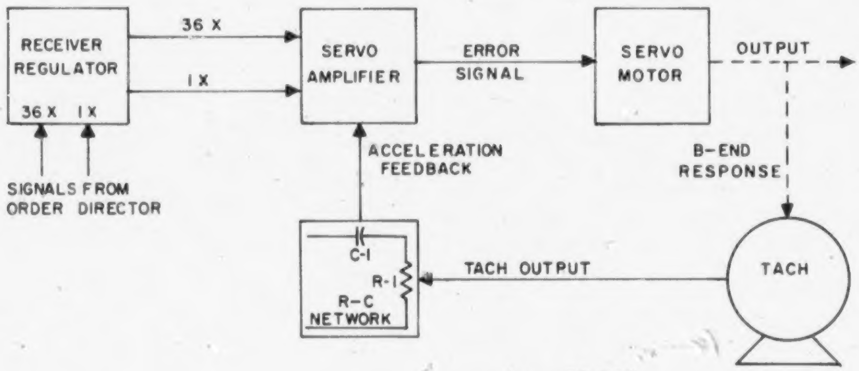
SRP POWER SUPPLY.—A step down transformer located in the power supply section of the servo amplifier is applied across stroke response potentiometer RAT-1. Two matched resistors connected in parallel with the SRP divide a 20-VDC input which provides from +10 volts to -10 volts (zero center) across RAT-1. One A-end stroking piston positions the wiper of RAT-1 so that when the A-end tilt plate is at neutral, the wiper of the SRP is at zero. The polarity of the output voltage depends upon the direction of the A-end's tilt plate movement.

The reference voltage for RAT-1 comes from a tachometer geared to the controlling director. Its output is supplied to the servoamplifier as a d.c. velocity signal. This signal represents the rate of velocity change of the input signal.

Acceleration Feedback

When you solve one problem, another usually arises, such is the case with velocity feedback. It causes velocity error: here is why. When the servo is following a Constant Velocity input signal, the tach or the potentiometer puts out a velocity signal even if the input and output shafts are in agreement. At this point there is no position error signal, but there is a velocity feedback signal at the input to the servoamplifier. This velocity signal causes the output to lag the input. The faster the constant velocity signal, the faster the servo moves, and the greater the velocity feedback signal. Therefore, the further the output will lag behind the input. This velocity lag problem can be solved with an integral control circuit (you study them next), which are used in conjunction with velocity feedback circuits. But there are other ways of skinning a cat. We can use the same feedback arrangement illustrated in figure 2-22 and insert a simple resistor-capacitor network between the tach and the amplifier. The new circuit is shown in figure 2-23 and is called an acceleration feedback circuit, but is still classified as output damping because the tach senses the output velocity of the servo.

A resistor (R1) is connected across the output of the tach, and the capacitor is in series with the tach. The capacitor (C1) is the key to the circuit's operation. When the servo is following a constant velocity input signal, the output of the tach is a steady d.c. voltage. From your study of electricity, you know that a capacitor blocks the flow of direct current. Therefore, no velocity signal gets through to the amplifier when the output shaft is moving at the same speed as the input shaft. The velocity feedback signal from the



53.263
Figure 2-23.—Acceleration feedback.

tach is blocked and does not oppose the error signal. But if the output shaft suddenly changes in speed (accelerates), then the tach puts out a fluctuating d.c. signal which looks like a.c. to the capacitor, and it passes the feedback signal on to the amplifier. Here the feedback signal opposes any change or error signal. Thus the output is restrained from changing its speed.

INTEGRAL CONTROL

The purpose of the integrating system is to reduce error between actual gun order and gun position when the system is tracking in remote control. This can be accomplished either electrically or by hydraulic devices. We will explain the electrical method here and the hydraulic method in chapter 5.

Power drives are required to follow constant velocity order signals. These signals occur, for example, when a gun director is following a target whose speed and range remain fairly constant. The input shaft to the gun mount's train order transmitter turns at a constant velocity (speed and direction) for a substantial percentage of time. Therefore, the power drive servo must respond to this type of input with as small an error as possible. But because there is always friction present, the output of the servo lags the position of the input shaft when both shafts are rotating at the same velocity. For example, if the input shaft is rotating at 10°/sec and the output shaft is moving at the same speed, but the angular position between them is 1° difference, then we have a velocity error due to laging.

To correct for velocity error, servos use integral control circuits. This type of circuit, like the output rate method, reduces velocity error to a minimum. The integral circuit modifies the error signal so that it is proportional to the length of time it exists, multiplied by the amplitude of the error signal. For example, suppose the output from a CX is four volts and it was produced by a constant error signal which lasted for one minute. If the same error signal lasted for only one-half minute, the output would be only two volts. You can see that if an error signal exists for a long time, its amplitude increases and an exaggerated error reducing action takes place. Or, the servo will overcorrect the error because the speed of the output shaft increases more than it normally would, and thus it catches up with the input shaft.

Figure 2-24 shows a simplified block diagram of an actual power drive servo. A simplified version of an integral control circuit is also illustrated. This circuit is located in the servo amplifier and is part of the compensating network.

Briefly, here is how the circuit works: The circuit is made up of two resistors and one capacitor. First the error signal is changed from a.c. to d.c. by a demodulator located in the servo-amplifier. The components of the integral circuit are such that the capacitor's voltage does not change when the error voltage changes rapidly. Only that portion of the changing error signal developed across R1 is passed on to the amplifier section of the servoamplifier. If there is an error signal of longer duration, the capacitor will charge, increasing the voltage input to the amplifier. Therefore, this type circuit is sensitive

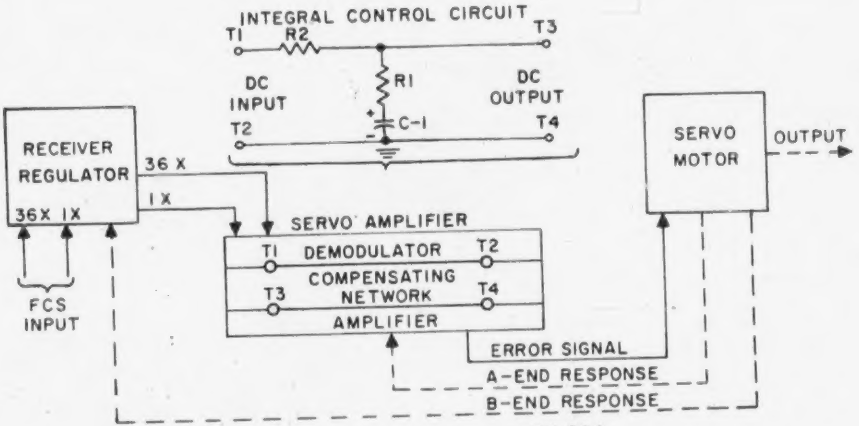


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Figure 2-24.—Integral circuit.

to constant or slowly changing error signals of the type you would expect from a velocity error. On the other hand the integral control circuit ignores rapidly changing error signals. Remember, the higher the frequency of the voltage impressed across an R-C circuit, the more the capacitor acts like a short circuit. Rapidly fluctuating d.c. signals will be split between R1 and R2, because the capacitor acts like a short circuit or zero resistance. R2 is much larger than R1, so most of the fluctuating voltage is dropped across R2. A much smaller portion of the rapidly changing error signal appears across R1. Since R1 is in parallel with the input to the amplifier, only a small signal voltage is amplified.

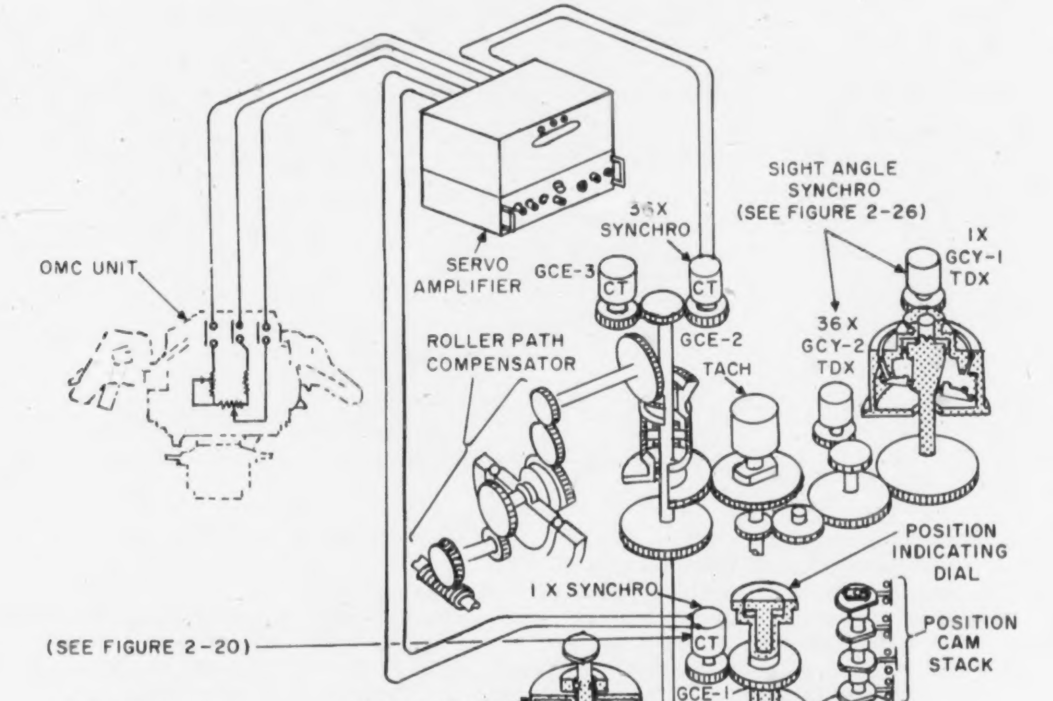
Now look what happens in the circuit when the error signal is steady or changes slowly. This is the kind of signal you would get when a velocity error exists. Initially, all of a constant error voltage would be distributed between R1 and R2, but the longer the error voltage is applied, the more C1 charges up. The increasing I-R drop across C1 adds to the drop across R1 and, since these two components are in parallel with the amplifier, their combined voltage will appear at the input terminals to the amplifier. In effect, the drive motor will overcorrect the error signal and the output will catch up with the input and correct for velocity error. In most synchro servosystems you will generally find that integral control circuits and devices operate with the fine error signal and not the coarse.

SYNCHRO GEARING

Synchro gearing is essential for continuously accurate operation of ordnance servosystems. They furnish gun mount position feedback information to the servoamplifier. They are also used to position limit stop cams, firing cutout mechanisms, and also furnish roller path tilt information which mechanically positions the rotors of elevation synchros to compensate for gun mount roller path tilt.

Figure 2-25 is a schematic diagram of synchro gearing used with a modern gun system. In this type synchro arrangement all the rotors of the synchros are turned by B-end response. The outputs from the synchros are channeled to many different units of a servosystem. Where more than one synchro is used in any one unit, only one synchro output is used at any one time. Synchro GCE-1 is for 1X operation and synchro GCE-2 is for 36X operation. Synchro GCE-3 is used for test purposes when in local control, and GCE-5 supplies position information to the firm control system. Synchros GCY-1 and GCY-2 provide sight angle correction information to a target acquisition sight. This sight is used for tracking targets when in local control.

In any synchro system it is important that the phase output of the 1X and 36X position synchros is the same. We remember from our study of synchros that if we reverse the S1 and S3 leads to a synchro we will change the phase of the synchro's output signal (fig. 2-4). Look at figure 2-22, you see that the stator


SIGHT ANGLE SYNCHRO (SEE FIGURE 2-26)
36X SYNCHRO
1X GCY-1 TDX
OMC UNIT
SERVO AMPLIFIER
GCE-3
CT
CT
GCE-2
36 X GCY-2 TDX
ROLLER PATH COMPENSATOR
TACH
POSITION INDICATING DIAL
I X SYNCHRO
CT
POSITION CAM STACK
(SEE FIGURE 2-20)
GCE-1
SERVO VALVE
WOBBLE GEAR
LIMIT-STOP RACK
SPEED REDUCER
TO FIRE CONTROL SYSTEM (SEE FIGURE 2-12)
TX
TO SYNCHRO POWER
OVERRIDE DEVICE
GCE-5
CAB UNIT
STROKE RESPONSE POTENTIOMETER
AUXILIARY GEAR PUMP
POSITION PLUS LEAD CAM STACK
MOTOR

53.265
Figure 2-25.—Synchro gearing.

leads S1 and S3 to GCT-2 are reversed. When B-end response turns the rotor of the 36X synchro, it also turns the rotor of the 1X synchro. If the 36X synchro rotor is turned by B-end response and turns in a clockwise direction, at the same time the rotor of the 1X synchro is being turned in a counterclockwise direction (fig. 2-22). If the input to GCT-2 was a normal connection S1 to S1 and S3 to S3, the phase of its output signal would be opposite of that of the 36X synchro. Since both synchro outputs are fed into the servoamplifier to null out the position signal and to stop the gun when it reaches its ordered position, both output signals from the synchros must be the same. By reversing S1 and S3 leads to GCT-2 the output of both synchros will be in phase. If the S1 and S3 leads were not reversed the synchros would fight each other and the gun would hunt across the ordered position and never settle down. It is very important to ensure that when a synchro is replaced in a system it is connected according to up-to-date electrical prints. The phase shift was caused by mechanical synchro gearing and compensated electrical by reversing S1 and S3 leads to GCT-2.

Position Indicator

We stated that the purpose of GCE-5 in figure 2-25 is to send to one or more fire control systems the latest position of a gun mount. This information can be useful to a ship's weapons officer when a weapon system has many gun mounts, launchers, and fire control systems. A TX can be used with many TRs (fig. 2-12) located in different fire control stations to indicate mount position. A TX and TR synchro setup can also be used for testing purposes.

Optical Servosystem

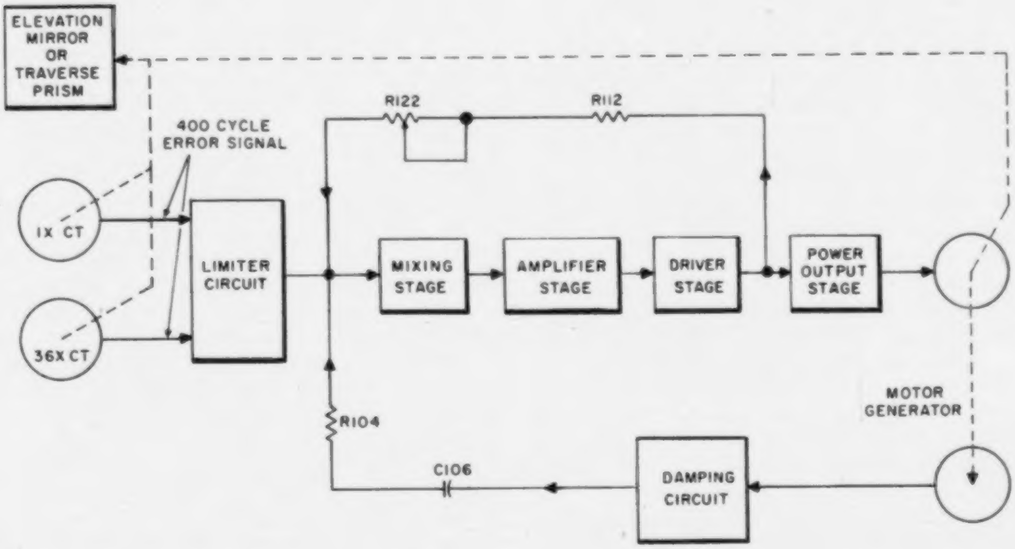
A target acquisition sight is used with a sight telescope in modern gun systems to locate and track low speed or surface targets during gun mount local control operation. These sights use a servo system which functions to continuously and accurately position the rotatable optical elements in accordance with synchro orders received from a fire control system.

The servo consists of two separate mechanisms—one for elevation and one for traverse. Each mechanism has a 1X and 36X CT, a servo motor generator, a gear train, and a servo amplifier. The operation of the servo system shown in figure 2-26 is as follows: To correct the telescope for sight angle, an electrical input from a fire control system (FCS) is applied to the sight angle synchros GCY-1 and GCY-2 (fig. 2-25), located in the elevation receiver regulator. The sight angle synchros combine this sight angle input and the elevation B-end response input into a single output signal and direct it to the telescope's elevation synchros. The sight angle synchros GCY-1 and GCY-2 are TDX type synchros and function to either add or subtract its two input signals. Their output signals are fed to two CTs located in the telescope's servo chamber in the form of coarse and fine synchro signals. The CTs also receive a servo response (feedback) signal representing the actual position of the optical elements. On the base of the two signals the CTs act as error detectors and generate and a.c. error signal. The error signal is fed to a limiter circuit (synchro changeover circuit) which selects either a fine or coarse signal. The error signal is then fed into a servo amplifier who's output controls a servomotor. The servomotor drives the optical elements to the ordered position. The signal is canceled out by the optical elements response to the controlling CT.

Again we have a basic synchrosystem designed not to move a large gun mount but only position a small mirror. As you can see, servosystems are used in many different ways in ordnance equipment. The important thing to remember about an ordnance servosystem is that it must continuously and accurately position its load whether it be a gun mount, turret, missile launcher, or a small optical mirror.

Servosystem Components

In the servosystem shown in figure 2-25, we used three different types of synchros. The control transformers (CTs) were used as error detectors, the torque differential transmitters (TDXs) were used as inputs to an optical servosystem (one servo controlling another), and a torque transmitter (TX) was used to furnish actual gun mount position to a fire control system. The type of synchros used in a servosystem is determined by the servo's purpose. The servo's purpose also determines the output device used to control the servo's load. The servo's load is driven by the output device (usually called a servomotor) whose function is to supply torque, power, and the dynamic characteristics required to position the servo's load. The types of servomotors used with ordnance servosystems are electric motors, amplidyne motor-generator



53.266
Figure 2-26.—Optical servosystem.

or electric-hydraulic units (A-end/B-end combinations). These systems are described briefly in subsequent paragraphs.

AMPLIDYNE SERVOSYSTEMS

Heavy guns can be trained and elevated by direct handwheel action through the gearing system. Naturally this relatively slow and difficult method is not normally used in battle, but it is necessary for certain adjustment or maintenance operations. To move the guns quickly, easily, and accurately in response to a signal, either an amplidyne or an electric-hydraulic servosystem can be used. For light to moderately heavy loads—such as missile launchers and 3-inch to 5-inch gun mounts—amplidyne power drives are reliable and accurate. Also, they are easier to maintain than the electric-hydraulic systems designed for heavier loads.

In figure 2-27 an amplidyne followup system has been reduced to its bare essentials. These are a pair of synchro-control transformers (illustrated as a single unit for the sake of simplicity), an amplifier, an amplidyne motor-generator, and a followup d. c. servomotor.

In the synchro-control transformer, the input to the stator is an order signal from a remote synchro transmitter. The position of the rotor represents the response of the load. The output of the synchro-control transformer is the a. c. error signal. Actually, two synchro-control transformers—a coarse and a fine one—are used. When the gun is within 3° of its ordered position, the fine synchro is automatically connected to control the system instead of the coarse one.

The control amplifier uses gas-filled electron tubes (called thyratons) for two purposes. First it rectifies the a. c. input; that is, it converts this input to a d. c. output whose magnitude and direction measure the amount and direction of error. Second, it amplifies the signal and produces two d. c. outputs that are fed to the control field windings in the amplidyne generator, as explained in the paragraphs following.

The amplidyne generator is a special adaption of one type of ordinary commercial d. c. generator. Such a generator has a wire-wound rotor that turns within the field of an electromagnet on the stator. The upper part of figure 2-28 shows a conventionally connected d. c. field schematic. Excitation power to the field is 100 watts d. c. to produce field FC. The arrow shows the direction of this field.

The larger circle between the two poles represents the rotating armature, which is driven

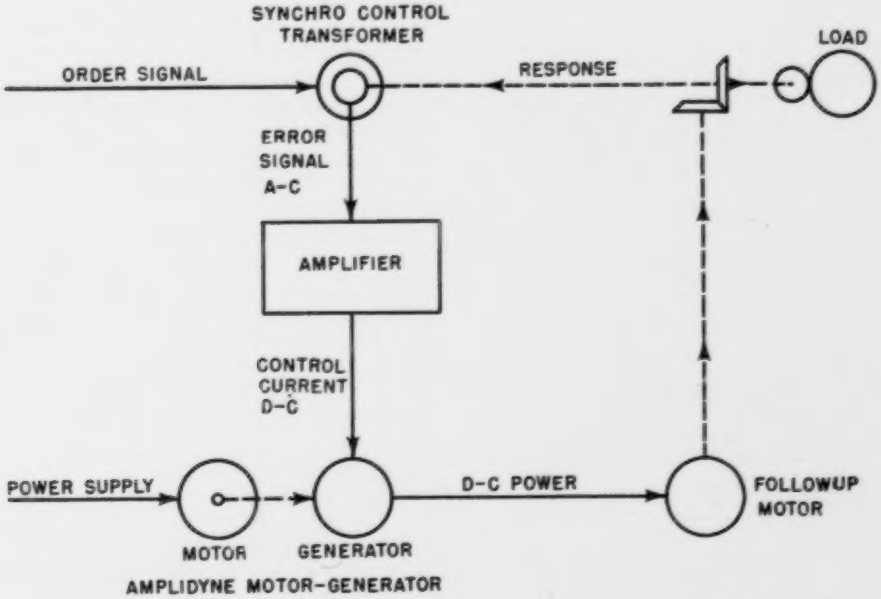


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Figure 2-27.—Essentials of an amplidyne followup system.

at constant speed by a motor (not illustrated). Rotation in field FC induces an a.c. voltage in the armature winding.

The inner circle in figure 2-28 represents the commutator. In the conventional d.c. generator, the commutator connects the armature output to an external d.c. load circuit by contact with a pair of stationary carbon brushes, 180° apart. The generated (or load) current as it passes through the armature winding creates its own magnetic field, FS. This field, called armature reaction, serves no useful purpose; indeed, it is a nuisance.

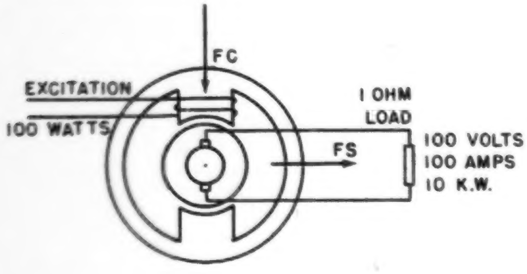
Normally, other things being equal, the power output of the generator will be proportional to the excitation power. This generator is assumed to be a 10-kw machine (100,000 watts output), and the excitation required is about 100 watts. The "amplification", therefore, is 100 to 1.

The first step in transforming this ordinary d.c. generator into an amplidyne generator is to short-circuit the two brushes as shown in the second part of figure 2-28. Now an immense armature current will flow, but if excitation is cut down to about 1 watt, FC is reduced, and 100 amperes again flow through the armature, producing the same armature reaction FS as before.

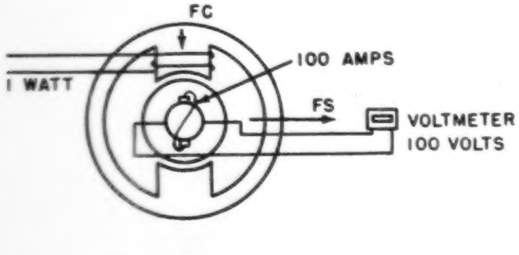
The next step is to add a second pair of brushes at right angles to the short-circuited pair, and to connect the load circuit over these brushes, as shown in the third part of the figure. Now, however, the output voltage becomes very low, because the new output circuit has created its own armature reaction, FZ, which opposes FC and greatly reduces its effect.

Now put a compensating winding, so connected that armature current passes through it, on the second pole of the electromagnet, as in the final part of the figure. This winding produces field FB to nullify FA and thereby allow FC to become fully effective again. The ordinary d.c. generator has now become a basic amplidyne generator in which full-load output is developed with 1-watt excitation ("amplification" of 10,000 to 1). Thus it can operate on very low excitation (e.g., the output of the amplifier in figure 2-27) and still furnish enough power to drive a large servomotor (the followup motor in figure 2-27).

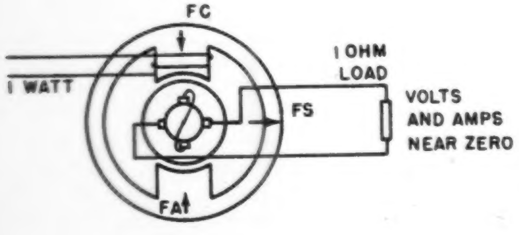
The amplidyne generator must control the direction of its followup motor's rotation, as well as its torque. To accomplish this, the amplidyne generator has two control fields instead of the one shown in the last part of figure 2-28. One of these is wound in the opposite direction to the other. The direction of FC and of generator



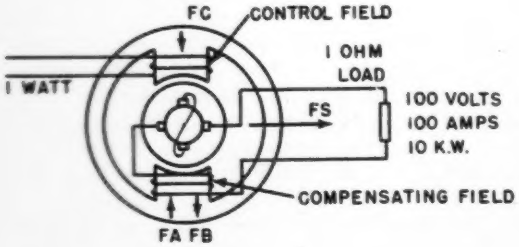
ORDINARY D-C
GENERATOR



BRUSHES SHORT
CIRCUITED AND
EXCITATION REDUCED



LOAD CONNECTED
TO NEW BRUSHES



COMPENSATING
FIELD ADDED

110.26
Figure 2-28.—The development of an amplidyne generator.

output depend on which receives more current from the amplifier. If the amplifier supplies equal currents to both control windings, generator output is zero and the followup motor stands still. When control winding currents differ, the followup motor will develop a torque whose direction depends on which current is greater, and whose magnitude depends on the amount of the difference.

The followup motor operates in a slave-to-master relationship with the amplidyne generator. Under a given load, its speed and direction of turning depend on the amount and direction of its d. c. input from the generator. Its output is mechanical power to drive the load in the right direction until the error signal has been reduced to zero.

ELECTRIC-HYDRAULIC SERVOSYSTEMS

The electric-hydraulic power drive has been developed to perform heavy gun laying reliability and rapidly. At this stage of your naval career, you should be familiar with at least the basic operating principles of this type drive—so, only a brief rundown will be given here. More detailed information on both amplidyne and electric-hydraulic power drives and control equipment will be presented in chapters to follow in this course.

The order signals to an electric-hydraulic system normally originate at a remote station. They enter through a complex unit sometimes called an indicator-receiver-regulator, but more often shortened to indicator-regulator. This unit contains synchros and related devices for (1) receiving the order signal and the response, (2) computing the error signal, (3) amplifying the error signal, and (4) transmitting this signal to the hydraulic system through an arrangement of valves and pistons.

A conventional a. c. electric polyphase induction power motor, connected to the ship's regular power supply, through a system of reduction gears drives the hydraulic pump (A-end) at virtually constant speed, regardless of A-end output.

The output of the A-end is hydraulic pressure to drive the B-end. The output of the B-end is mechanical action through a shaft and pinion. The input the B-end receives from the A-end determines the direction, speed, and duration of its output. In turn, the direction and amount in train or elevation depend on the output of the B-end to the gun's gearing system.

Figure 2-29 shows the sequence of operations when the mount is trained in automatic control. (Compare this figure with figure 2-27 showing the essentials of an amplidyne system.) The gun order signal enters the indicator-regulator. There the order signal is compared with the response, and the error signal is generated and amplified. The amplified error signal positions the A-end socket ring, thus regulating A-end output. A-end output drives the B-end, which, in turn, drives the training pinion. Mechanical response from the gearing is an input to the indicator-regulator, where, with the order signal, it combines to generate the error signal. As gun position approaches synchronism with the gun order signal, the error signal decreases, becoming zero or null when gun position equals gun order.

Guns, however, are far from being the only ordnance equipment that must be moved smoothly, rapidly, and accurately in response to incoming signals. Missile launchers and certain types of projectors have control arrangements similar, in many features, to those used with conventional gun mounts. By their nature, systems designed to launch guided missiles must be capable of operating even more swiftly, accurately, and dependably than any except the newest gun systems. As in conventional guns, the designer's choice of amplidyne or electric-hydraulic drive is governed largely by the weight and other physical features of the given system.

SERVOSYSTEM RATINGS

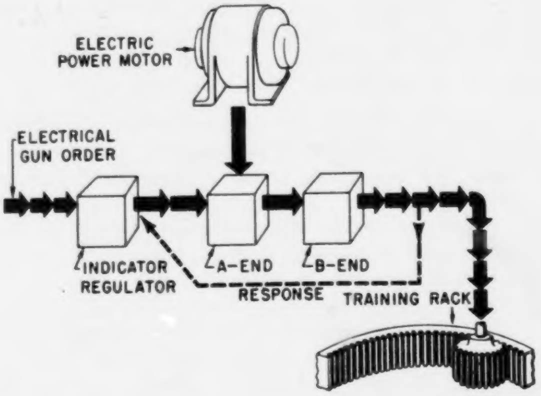
Servosystems are qualitatively rated in accordance with the following characteristics.

STATIC ERROR is the angular lag between the input and output under static conditions. A low figure is desirable.

STATIC ERROR UNDER LOAD is the angular lag produced between input and output by applying a specific torque to the output. A low figure is desirable.

VELOCITY FIGURE OF MERIT is the figure obtained by dividing the velocity of the output, expressed in degrees per second, by the angular lag between output and input, expressed in degrees, when the system is moving its load at a constant speed. It indicates how quickly the system responds to a constant input. A high figure is desirable.

DAMPING CONSTANT is related to the transient response of a servo. An overdamped servo is sluggish and usually responds to a change without overshooting. A slightly underdamped servo usually gives a quick response to practically no oscillation. A greatly underdamped servo usually will overshoot badly and oscillate for some time after a change in position is called for.



110.27
Figure 2-29.—A train power drive in automatic control.

ACCELERATION FIGURE OF MERIT is the ratio between a constant acceleration of the system, expressed in degrees per second, and the angular lag between output and input, expressed in degrees. A high figure indicates system ability to follow an increasing or decreasing input accurately and rapidly.

Zeroing Synchros

If synchros are to work together properly in a system, it is essential that they be correctly connected and aligned in respect to each other, and to the other devices, such as directors and guns, with which they are used. Needless to say, the best of ordnance equipment would be ineffective if the synchros in the data transmission circuits were misaligned electrically or mechanically. Since synchros are the heart of the transmission systems, it only stands to reason that they must be properly connected and aligned before any satisfactory shooting can be expected.

Electrical zero is the reference point for alignment of all synchro units. The mechanical reference point for the units connected to the synchros depends upon the particular application of the synchrosystem. As a GM, on board ship, your primary concern with mechanical reference point will be the centerline of the ship for gun train and the standard reference plane for gun elevation. Remember that whatever the system, the electrical and mechanical reference points must be aligned with each other.

There are two ways in which this alignment can be accomplished. The most difficult way is to have two men, one at the transmitter and one at the receiver or control transformer, adjust the synchros while talking over sound power telephones or some other communications device. The better way is to align all the synchros to electrical zero. Units may be zeroed individually, and only one man is required to do the work. Another advantage of using electrical zero is that trouble in the system always shows up in the same way. For example, in a properly zeroed TX-TR system, a short circuit from S2 to S3 causes all receiver dials to stop at 60° or 240°.

In summary, zeroing a synchro means adjusting it mechanically so it will work properly in a system in which all other synchros are zeroed. This mechanical adjustment is accomplished normally by physically turning the synchro rotor or stator. The methods for zeroing synchros are explained in GMG 3/2, NP 10185-A and Synchro Handbook MIL-HDBK 225 (AS).

MAINTENANCE

Synchro units require careful handling at all times. NEVER force a synchro unit into place, NEVER drill holes in its frame, NEVER use pliers on the threaded shaft, and NEVER use force to mount a gear or dial on its shaft.

Synchros are no longer considered as repairable items. Replaced synchros should be disposed of in accordance with current instructions. Unless in an emergency with no replacement available, NEVER take a unit apart or try to lubricate it.

Before testing a new installation and before hunting trouble in an existing system, first be certain all units are zeroed. Also, be sure the device's mechanical position corresponding to electrical zero position is known before trying to zero the synchros. The mechanical reference position corresponding to electrical zero varies; therefore, it is suggested that the instruction books and other pertinent information be carefully read before attempting to zero a particular synchrosystem.

Troubleshooting Synchrosystems

Shipboard synchro troubleshooting is limited to determining whether the trouble is in the synchro or in the system connections; but if something is wrong with the unit, replace it. Generally, there are two major categories of troubles occurring in synchrosystems. These are (1) those likely to occur in new installations, and (2) those likely to occur after the system has been in service a while.

New Installations

In a newly installed system, the trouble probably is the result of improper zeroing or wrong connections. Make certain all units are zeroed correctly; then check the wiring. Do not trust the color coding of the wires. Best check them out with an ohmmeter. A major source of trouble is improper excitation. Remember, the entire system must be energized from the same power source for proper operation.

Established Installations

In systems which have been working, the most common trouble sources are:

Switches—Shorts, opens, grounds, corrosion, wrong connections

Nearby equipment—Water or oil leaking into synchro from other devices. If this is the trouble, correct it before installing a new synchro.

Terminal boards—Loose lugs, frayed wires, corrosion, and wrong connections

Zeroing—Units improperly zeroed.

Wrong connections and improper zeroing in any system are usually the result of careless work or inadequate information. Do not rely on memory when removing or installing units. Refer to the applicable instruction book or standard plan. Tag unmarked leads or make a record of the connections. Someone else may need the information.

IF IT WORKS—LEAVE IT ALONE.
IF IT GOES BAD—REPLACE IT.

CHAPTER 3

AMPLIDYNE POWER DRIVES

The purpose of any power drive is to provide the controlled power required to move a prescribed load to a designated position. Power is fairly easy to obtain, but in order to be effective it has to be controlled. That is, the correct amount of power must be applied, in the right direction, for the proper length of time, to move the load to a designated position.

Think of the problems the requirements of a gun mount power drive present. The load weighs several tons; the accuracy demanded is measured in minutes of arc; the signals used to control the drive are bi-directional at variable speeds; and the response to a signal has to be almost instantaneous. The equipment has to be rugged to withstand gun shock and weather, yet reliable so as to operate with a minimum of maintenance. The amplidyne drive meets all of these requirements. It is one of the most widely used power drives in the Navy. It takes its name from the special type d-c generator it uses.

Power Drive Mk 35 is of the amplidyne type and provides the controlled power required to train and elevate a 3"/50 gun mount or the Guided Missile Launcher Mk 128. This launcher was built from a modified 3"/50 gun mount and is used with the Guided Missile Launching System (GMLS) Mk 25 which functions as part of the Basic Point Defense Surface Missile System (BPDSMS). The BPDSMS provides a tactical weapon for all-weather defense against air and limited surface targets. These systems are installed aboard either auxiliary or combat vessels and are maintained by personnel of the GMG rating. Once you understand the basic functions of the components of a Mk 35 power drive you can understand all amplidyne drives. For this reason we will explain how the Mk 35 power drive controls the movements of a 3"/50 gun mount and point out the difference between the gun system and the missile system. You will also find that there is some similarity between the electric drive and the hydraulic drive. A different type of energy is employed, but it is put to the same use. Since you are probably more familiar with hydraulic drives, the similarity will be pointed out where possible.

FUNCTION OF THE POWER DRIVE

The equipment contains two separate but almost identical power drives. One of them controls the gun mount's/missile launcher elevation angle, and the other controls its train angle. The power drives are operated in one of two modes: "Automatic"/Remote Mode or "Local." In either mode, both drives are operated simultaneously; you cannot place one in Automatic and the other in Local.

There is no manual operation; however, handcranks are provided for use in stowing and maintenance. The handcranks are not permanently installed, but are stowed on the mount. (For the remainder of this chapter the word "armament" is used as a synonym for gun mount/missile launcher).

AUTOMATIC CONTROL

Power Drive Mk 35, and hence its armament, are normally controlled automatically by train and elevation order voltages generated by a remote director or computer (fig. 3-1). Position order voltages are applied to synchro control transformers in receiver regulators located on the armament. The synchros compare the actual position of the armament with the ordered position. If the actual position of the armament differs from the ordered position, the synchros develop a-c error voltages. These voltages are transmitted to the Amplifier Mk 40 where they are amplified and rectified. The polarity of the rectified voltage is determined by the direction of the error, while the amplitude of the voltage is determined by the amount of error. This d-c error voltage is transmitted to the amplidyne generator which

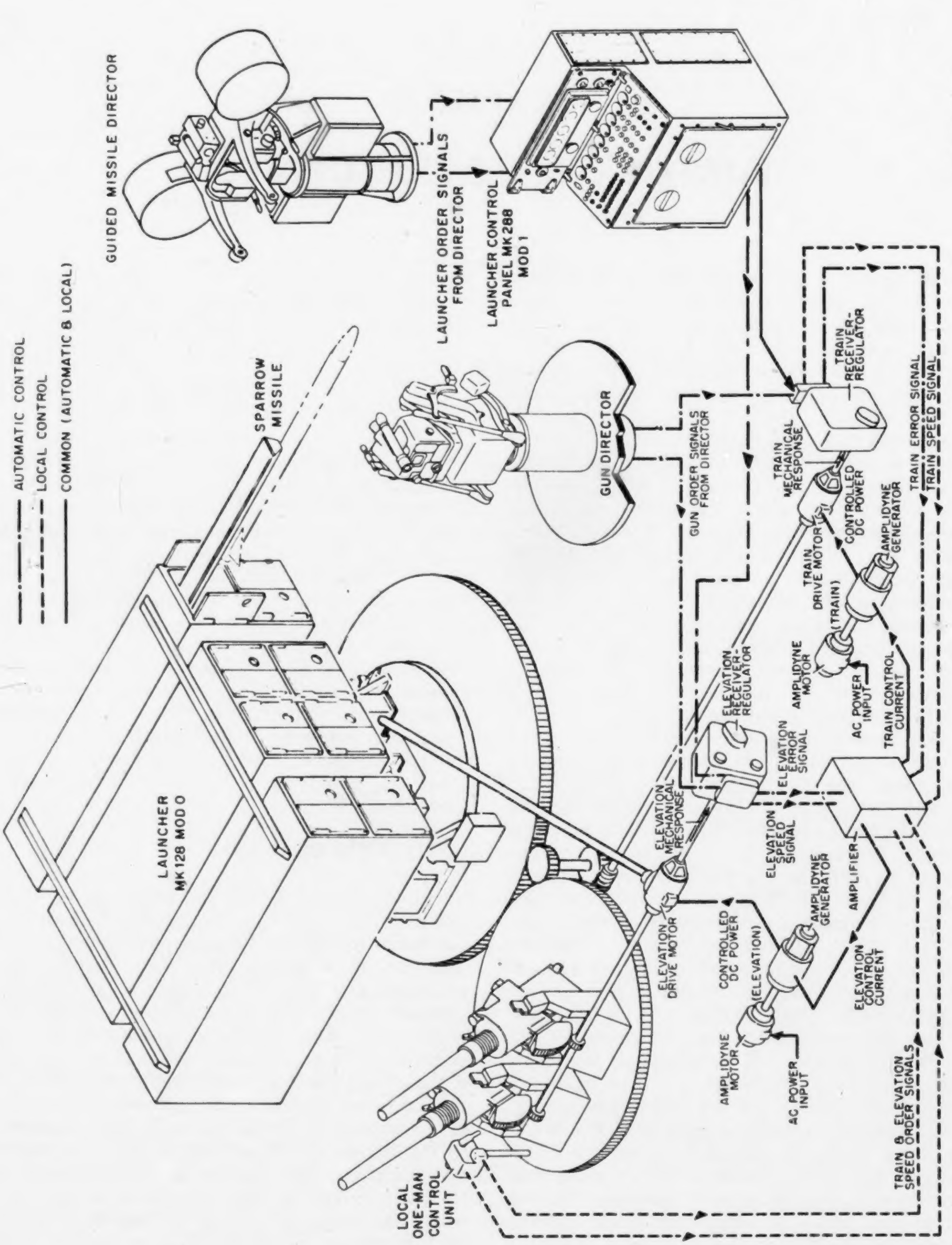

AUTOMATIC CONTROL
LOCAL CONTROL
COMMON (AUTOMATIC & LOCAL)
GUIDED MISSILE DIRECTOR
SPARROW MISSILE
LAUNCHER ORDER SIGNALS FROM DIRECTOR
LAUNCHER CONTROL PANEL MK 288 MOD 1
LAUNCHER MK 128 MOD 0
GUN DIRECTOR
GUN ORDER SIGNALS FROM DIRECTOR
TRAIN MECHANICAL RESPONSE
TRAIN RECEIVER-REGULATOR
CONTROLLED DC POWER
AMPLIDYNE GENERATOR
TRAIN ERROR SIGNAL
TRAIN SPEED SIGNAL
TRAIN DRIVE MOTOR
(TRAIN)
AMPLIDYNE MOTOR
AC POWER INPUT
TRAIN CONTROL CURRENT
ELEVATION RECEIVER-REGULATOR
ELEVATION ERROR SIGNAL
ELEVATION MECHANICAL RESPONSE
ELEVATION SPEED SIGNAL
AMPLIFIER
ELEVATION DRIVE MOTOR
CONTROLLED DC POWER
(ELEVATION)
AMPLIDYNE GENERATOR
ELEVATION CONTROL CURRENT
AMPLIDYNE MOTOR
AC POWER INPUT
TRAIN & ELEVATION SPEED ORDER SIGNALS
LOCAL ONE-MAN CONTROL UNIT

Figure 3-1.—Amplidyne power drive used with the 3"/50 twin mount or Guided Missile Launching System Mk 25.

53.37(53C)

responds by producing train and elevation control power. This power is applied to the armament's train and elevation drive motors, which move to the ordered position. This action returns the train and elevation error voltages to zero by re-positioning the synchro control transformers in the receiver regulators. The armament therefore comes to rest at the ordered position.

LOCAL CONTROL

In a gun system if the Automatic mode of control is disabled, the power drive can be controlled locally by the train and elevation order voltages generated at either of two One-Man Control (OMC) stations. (One of these stations is shown in figure 3-1.) The local control stations are called the "Local-Surface" and "Local-AA" station. At the Local-Surface station is Control Panel Mk 62 (fig. 3-2.) where the selection of mode of control is Local, the station which is to control the mount (either Local-Surface or Local-AA) is also selected here. Only one station at a time can control the mount.

In the GMLS the local control mode is used only for testing and maintenance. A Launcher Control Panel (LCP), figure 3-3, contains all the controls for operating the GMLS in local mode and also contains indicators for monitoring the status of the GMLS. The GMLS can be operated in local only when the Local-Remote select switch on the LCP is positioned to local.

Gun Control Station

The local operator moves the handles of his one-man control station (fig. 3-4) to develop gun order voltages. To change elevation, the handles are tilted about their mounting axis. The direction in which the upper ends of the handles are moved is the direction in which the gun will move. To change gun train, the entire one-man control unit is displaced about its mounting axis. In both train and elevation the degree of displacement or tilt governs the speed at which the gun moves. When the safety switch on the left-hand handle is closed, it energizes the local circuits.

Control by the two local stations is functionally the same. Let us use Local-Surface and elevation drive to see how the local control systems function.

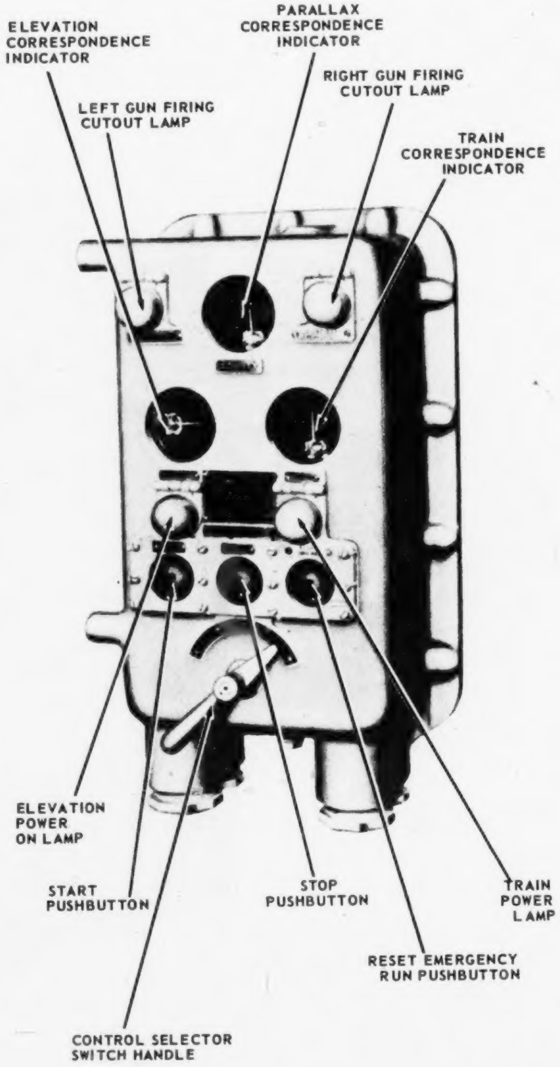
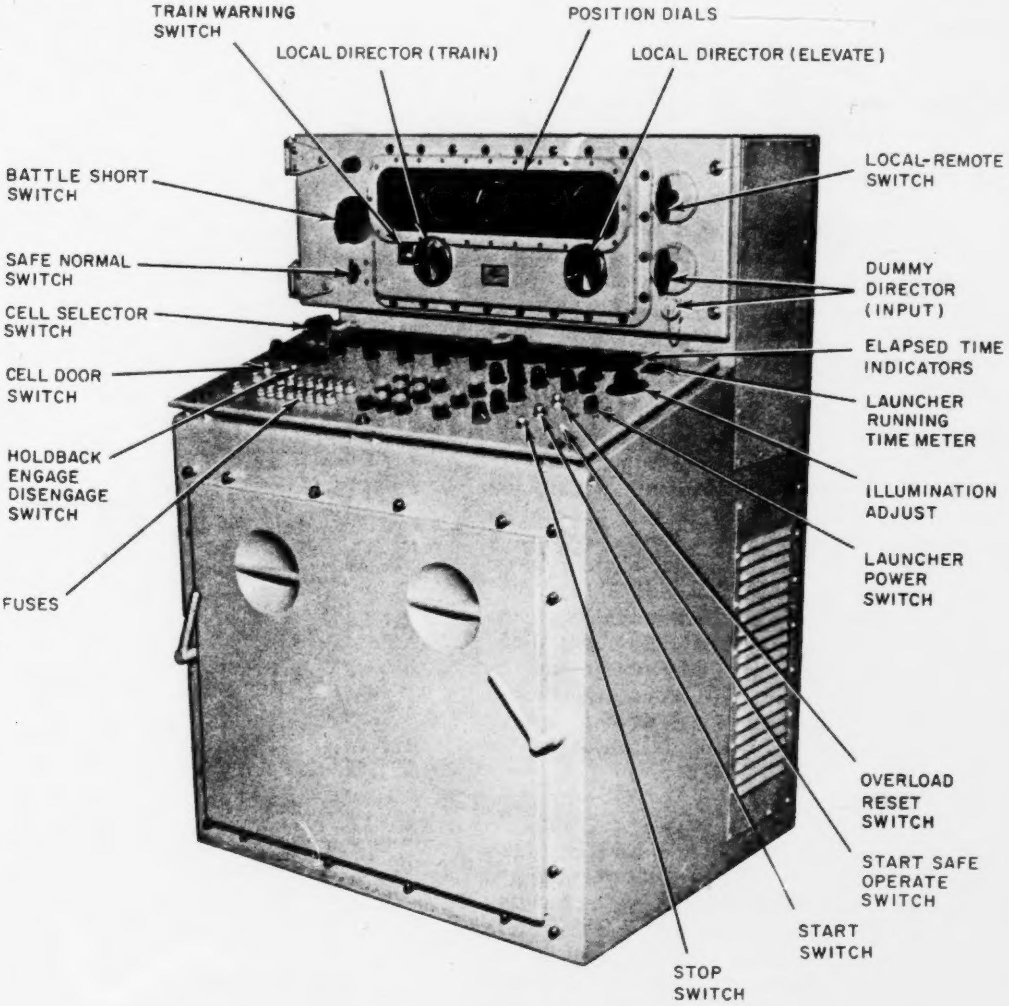

ELEVATION CORRESPONDENCE INDICATOR
PARALLAX CORRESPONDENCE INDICATOR
RIGHT GUN FIRING CUTOUT LAMP
LEFT GUN FIRING CUTOUT LAMP
TRAIN CORRESPONDENCE INDICATOR
ELEVATION POWER ON LAMP
START PUSHBUTTON
STOP PUSHBUTTON
TRAIN POWER LAMP
RESET EMERGENCY RUN PUSHBUTTON
CONTROL SELECTOR SWITCH HANDLE
53.38

Figure 3-2.—Control Panel Mk 62 of local-surface station.

To change the elevation angle of the guns, the local operator tilts the handles of his one-man control in the direction he wants the gun to move. The further he tilts the handles, the faster the guns move. As he tilts the handles, the one-man control generates a speed order voltage and applies it to Amplifier Mk 40, where it produces a d-c elevation control current. This current energizes the control field of the amplidyne generator, thereby causing the amplidyne to generate d-c power for the drive motor. The drive motor starts to move the guns, and mechanical response to the receiver regulator drives

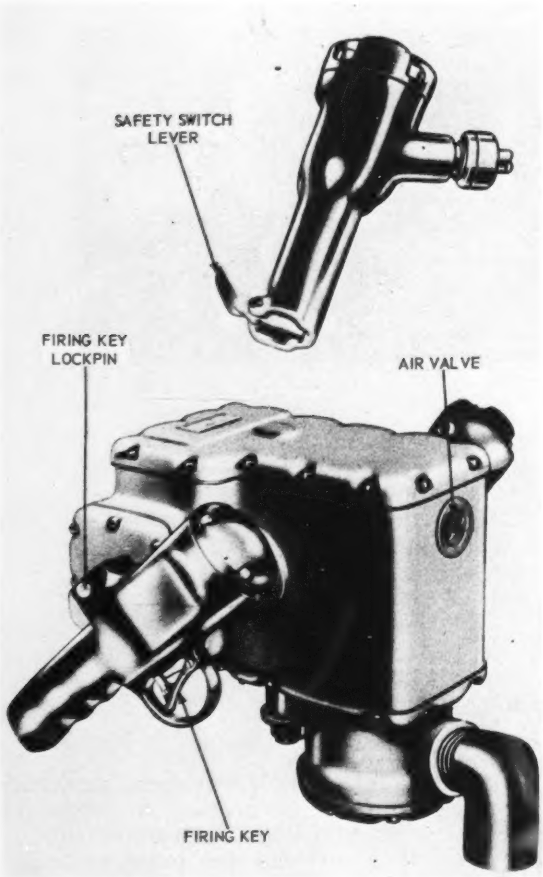

TRAIN WARNING SWITCH
LOCAL DIRECTOR (TRAIN)
POSITION DIALS
LOCAL DIRECTOR (ELEVATE)
BATTLE SHORT SWITCH
LOCAL-REMOTE SWITCH
SAFE NORMAL SWITCH
DUMMY DIRECTOR (INPUT)
CELL SELECTOR SWITCH
ELAPSED TIME INDICATORS
CELL DOOR SWITCH
LAUNCHER RUNNING TIME METER
HOLDBACK ENGAGE DISENGAGE SWITCH
ILLUMINATION ADJUST
LAUNCHER POWER SWITCH
FUSES
OVERLOAD RESET SWITCH
START SAFE OPERATE SWITCH
START SWITCH
STOP SWITCH

53.267
Figure 3-3. — Launcher Control Panel.

a tachometer generator. The tachometer generates a gun speed voltage and applies it to the amplifier, where it opposes the speed order voltage. The amplitude of the gun speed voltage increases as the speed of the drive motor increases.

The speed of the drive motor will continue to increase until the tachometer voltage reaches a certain level. At this point no further increase in mount speed is possible until the operator moves his OMC further off center.

When the operator returns his control unit to neutral, the gun order signal is removed. Because of inertia, the mount tends to continue driving. The tachometer, still generating voltage, continues to apply feedback to the amplifier in opposition to the original signal, the feedback signal causes the mount to slow down.



53.39
Figure 3-4.—One-man control unit.

As the mount slows down, the tachometer feedback (which is dependent on mount speed) decreases. Thus the tachometer generator voltage brings the mount to a smooth stop.

Local Director

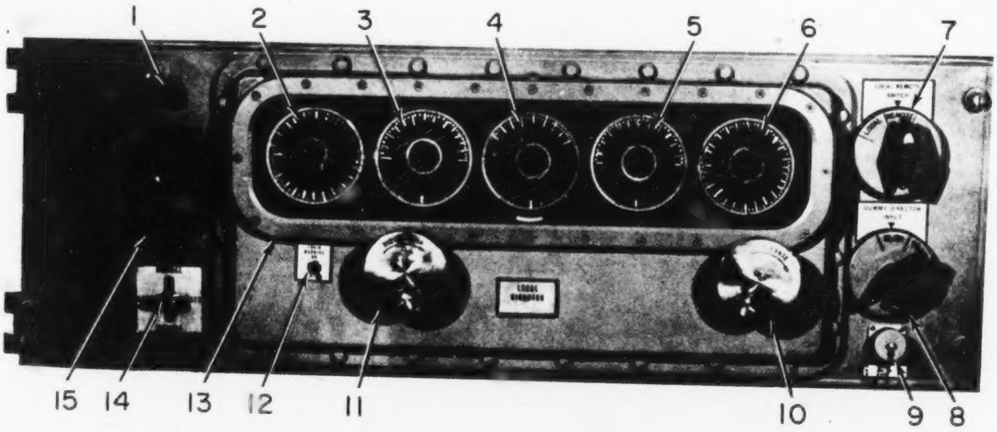
The difference between local control operation of a gun mount and missile launcher is that a local director located in the LCP contains two elevation synchro transmitters, one fine and one coarse. These synchros are geared to a handwheel for manual positioning, as shown in figure 3-5, and supply the control signals for local mode operation. A dial, visible to the operator at the LCP, is connected to the shaft of each synchro to indicate the ordered position. To change the elevation angle of the launcher guides, the local operator turns a handwheel located on the LCP in the direction he wants the launcher guides to move. The faster he turns the handwheel the faster the guide will elevate or depress. As he moves the handwheel, he generates a signal which is applied to the Amplifier Mk 40, where it produces a d-c elevation control current. This current controls the amplidyne generator in the same manner as described for gun mount local control operation.

AMPLIDYNE GENERATOR

The amplidyne generator is the heart of the Power Drive Mk 35. This d-c generator is the instrument that amplifies a low power electrical signal into one strong enough to drive a gun mount or launcher. Its output is the input to the drive motors of the gun/missile system. The direction of gun mount or missile launcher movement is determined by the polarity of the generator output. (Now is the time to review Basic Electricity, NAVPERS 10086, latest revision, if the principles of d-c generators are hazy in your mind.)

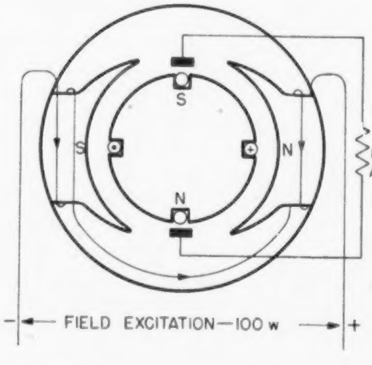
Any d-c generator can be used as an electric power amplifier. Its amplification factor is approximately 100. This means that if you apply one watt to its excitation field, the generator will deliver approximately 100 watts to the load. Amplification occurs when the generator rotor cuts the magnetic field supplied by the excitation current. Thus the mechanical movement of the rotor is the source of the output power. (Remember that a generator converts mechanical energy to electrical energy.)

Let's look at an amplidyne generator, part by part, to see how it can have an amplification factor of 10,000 when a normal generator has an amplification of only 100. First, let's look at an ordinary d-c generator (fig. 3-6). This is a separately excited generator, with a 100-watt external supply. The field windings set up a north and south pole, as shown in the figure. A magnetic field is established between the poles by current flow in the field excitation winding. The rotor or armature rotates in this field. The windings on the armature cut the lines of magnetic flux, and a voltage is induced in the armature windings. Current is taken from the armature windings by brushes mounted on the commutator, and delivered to the load. A peak output of 10,000 watts can be delivered.



1 BATTLE SHORT INDICATOR (DSB1)
2. TRAIN COARSE DIAL (GCTD1)
3. TRAIN FINE DIAL (GCTD2)
4. CABLE TWIST DIAL (BCTD1)
5. ELEVATION COARSE DIAL (GCED1)
6. ELEVATION FINE DIAL (GCED2)
7. LOCAL-REMOTE SWITCH (S1C1)
8. DUMMY DIRECTOR INPUT SWITCH (SMS2)
9. DUMMY DIRECTOR INPUT JACK (J4)
10. ELEVATE HANDWHEEL
11. TRAIN HANDWHEEL
12. TRAIN WARNING ON-OFF SWITH (SMT1)
13. LOCAL DIRECTOR ASSEMBLY
14. SAFE-NORMAL SWITCH (SMP5)
15. BATTLE SHORT SWITCH (SMB1)

53.268
Figure 3-5. — Local Director Assembly.



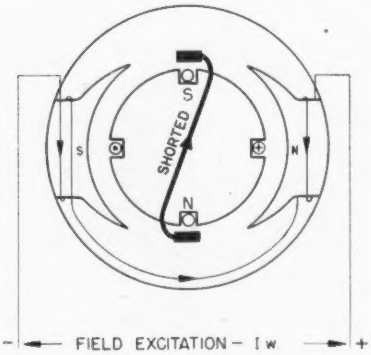
53.40
Figure 3-6. — Ordinary d-c generator.

In this, as in all d-c generators, an armature magnetic field is created by armature current. This is called the quadrature field, or cross field. It is perpendicular to the excitation field. This is the cause of armature reaction within the generator, and is an unwelcome feature of the normal generator.

In chapter 2, we saw an ordinary d-c generator transformed into an amplidyne generator with the making of a few small, but consequential, changes in its makeup. Let's now take a closer look at this transformation.

The first step in building our amplidyne generator is to short out the brushes (fig. 3-7). This establishes a path of very low resistance for the induced voltage in the armature winding under the brushes; consequently, we will have a large current in the winding. So we can now reduce the excitation and obtain the same armature current as in an ordinary generator.

If we reduce the field excitation by a factor of 100, we reduce the field flux, which in turn reduces the induced voltage in the armature.



53.41
Figure 3-7.—Quadrature brushes shorted.

But the reduced armature voltage is now forcing current through a short-circuited armature winding. The shorted armature produces the same armature current as the loaded armature in an ordinary generator, but with only 1/100 as much field excitation.

The current flow in the armature is used to establish the quadrature or cross magnetic field. This is the same as in any ordinary generator. Figure 3-8A shows the excitation field flux, and figure 3-8B shows the flux caused by armature current. Notice that they are 90 degrees apart.

When current flows in both the field and armature circuits, the two resulting magnetomotive forces distort each other. They twist in the direction of rotation of the armature. This action causes the mechanical (no load) neutral plane, AB figure 3-8C to advance to the electrical (load) neutral plane A'B'. The amount that the neutral plane shifts is proportional to the load on the generator because the amount of cross-magnetizing flux is directly proportional to the amount of current flowing in the armature. The axis A'-B', is the line in which the shortened brushes lie. In the amplidyne generator the shorted brushes are called the quadrature brushes.

Load Brushes

The quadrature field is the source of our output power. The windings of the armature cut the lines of flux in the quadrature field, and a voltage is induced. Be sure you understand that only the armature winding that is passing under the shorted brushes is short circuited. The other windings have normal resistance. We now add another set of brushes called the load or direct axis brushes (fig. 3-9). The axis of these brushes is perpendicular to that of the shorted brushes. The load brushes bear against the commutator, and take off the current induced in the armature windings by the strong quadrature field.

Compensating Winding

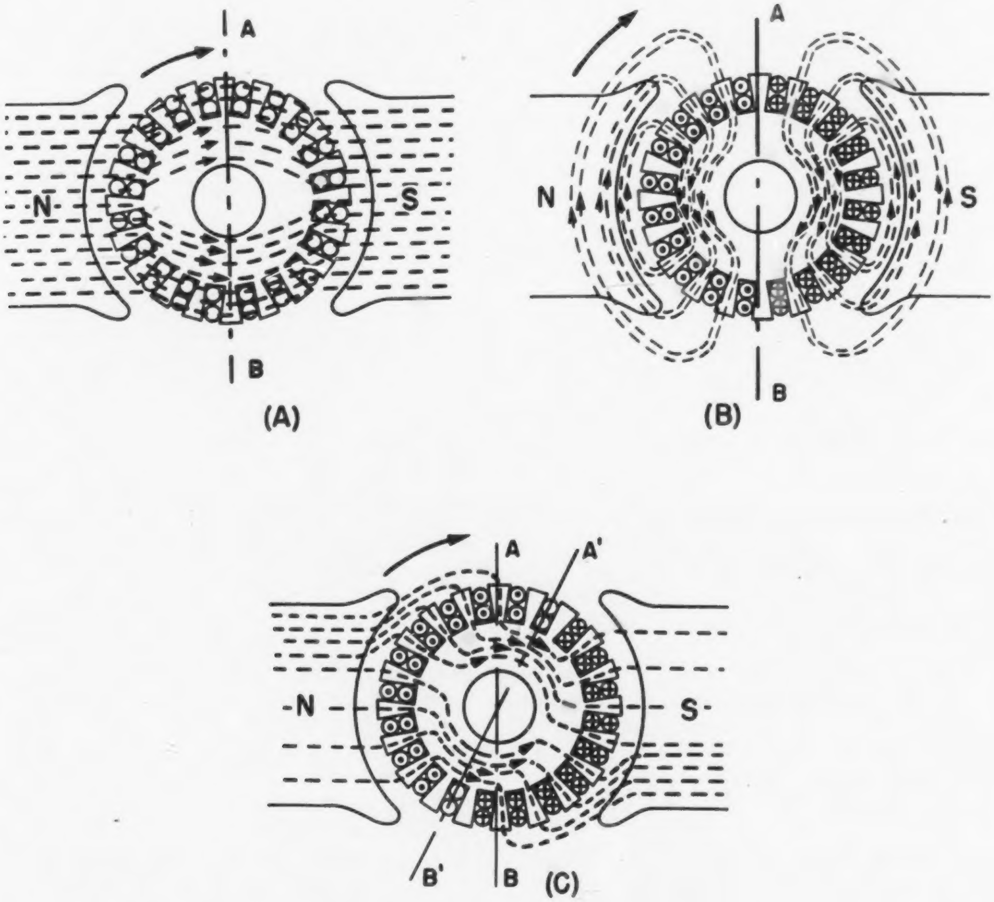
If our amplidyne generator is to work under a load, we need another winding. As soon as we have load current in the armature, we automatically establish another magnetic field due to armature reaction. The field is 90 degrees away from the load brushes, as in an ordinary generator. But in the amplidyne generator this puts the field caused by armature reaction in the same plane as our relatively weak excitation field. Because this field opposes the excitation field, it causes the power output to drop off rapidly.

What we need is another winding to set up a field which will oppose the field created by the load current. We will call this the compensating winding and connect it in series with the load, as in figure 3-10. Any current delivered to the load will pass through the compensating winding, and create a magnetic field proportional to the load current. The windings are wound so that the field they set up will oppose the armature load current field. The two fields will be equal and opposite, and will therefore cancel one another. With the cancellation of load flux, the power output is normal.

CONTROL WINDING

We have a power amplification of 10,000 to 1. Now we must be able to control it. If we are to use this amplidyne generator to drive a gun mount, we must be able to control both the direction and the amount of output power.

Until now, we have assumed that the signal going into the generator — the excitation voltage — is applied to a single control winding. Now let's split the control winding into two separate windings, and let them receive d-c inputs of opposite polarity, as in figure 3-11. The resulting control fields oppose each other. If the inputs to the two control windings are equal and opposite, the fields they create will cancel. With no control field flux to create a quadrature flux, there's no output. This condition is shown in figure 3-11A.



A. Field flux
B. Armature flux
C. Resultant flux

53.42

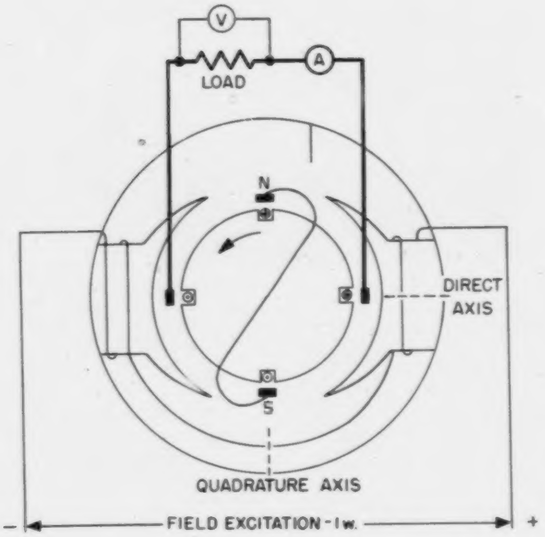
Figure 3-8. — Flux distribution in a d-c generator.

Figure 3-11B shows the inputs unbalanced, with the current in winding F1-F2 the stronger. Now the control fields no longer cancel one another, for the field from winding F1-F2 is stronger. We will have an output, whose strength is determined by the difference in the control windings' signal strength. Notice the direction of the output current.

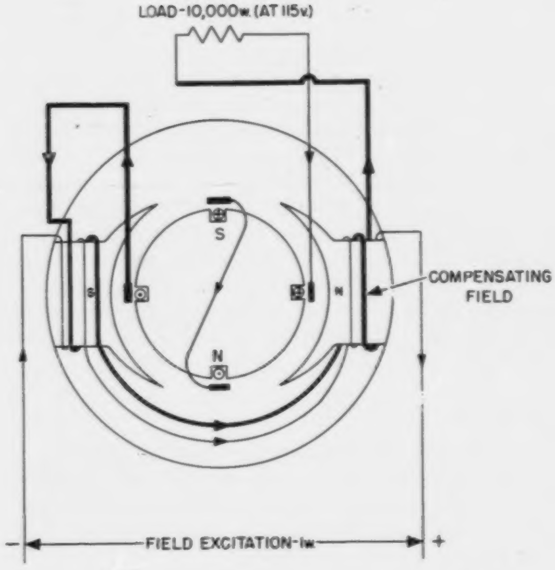
Figure 3-11C is the exact opposite of figure 3-11B; the F3-F4 control field is now stronger. Notice that the output is reversed. You can see, then, that the amount of output is determined by the resultant between the input signals applied to the control windings. And the polarity or direction of the output is determined by which control winding receives the larger input signal.

HOW THE CONTROL IS USED

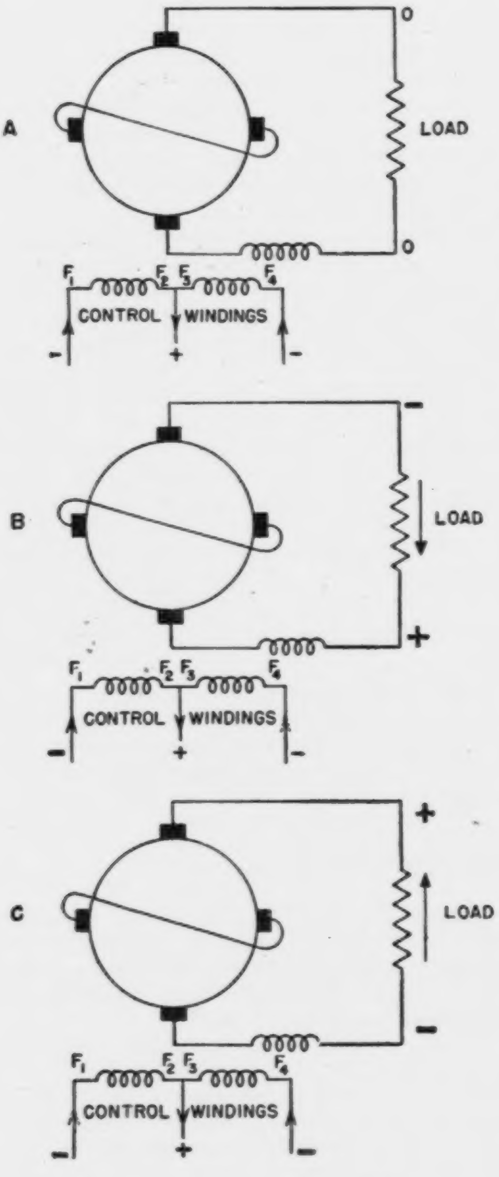
Here's an example that will show you how the amplidyne control is used. The control windings are connected to the output of an


V
LOAD
A
N
S
DIRECT AXIS
QUADRATURE AXIS
FIELD EXCITATION - Iw.
-
+

53.43
Figure 3-9.—Connecting a load.


LOAD-10,000w. (AT 115v.)
S
N
COMPENSATING FIELD
FIELD EXCITATION-Iw
-
+

53.44
Figure 3-10.—Compensating windings.


A
LOAD
0
0
F1
F2
F3
F4
CONTROL
WINDINGS
-
+
-
B
LOAD
-
+
C
LOAD
+
-

53.45
Figure 3-11.—Two control fields.

amplifier, whose input signals come from train synchro control transformers on a gun mount. The F1-F2 control winding receives signals for left train. The F3-F4 control winding receives signals for right train. The amplidyne output is connected to the train drive motor.

As long as the two signals are balanced, there is no output from the amplidyne. That means that there is no input to the drive motor, and the mount is stationary.

But when the F1-F2 input becomes stronger than the F3-F4 input, the amplidyne amplifies the difference between the two inputs. The output of the amplidyne has the F1-F2 polarity, and the drive motor rotates for left train.

Just the opposite happens when F3-F4 becomes stronger than the F1-F2 input. Again the amplidyne amplifies the difference between the two inputs. But now the amplidyne output is reversed and the drive motor rotates for right train.

Now let's say that the difference between the F1-F2 and F3-F4 inputs becomes greater. This increases the control field strength, and thereby increases the amplidyne output. The increased output applies more torque to the drive motor. The gun mount moves faster because of the greater difference between the control windings' inputs.

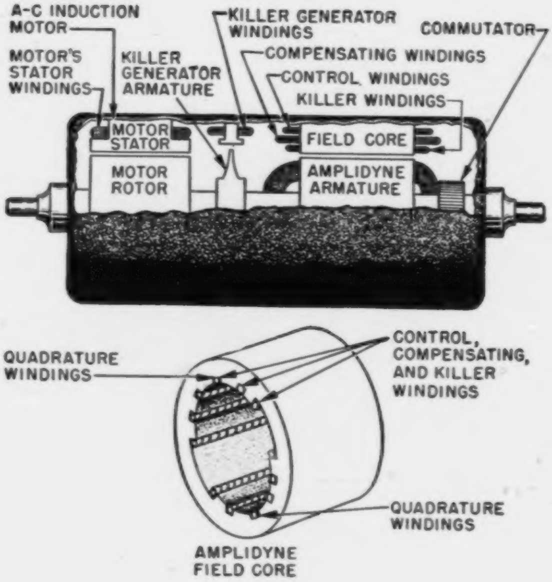
ADDITIONAL FIELDS

What we have just discussed is a basic amplidyne generator. We will now take up some improvements that will give us more accurate power control, more sensitivity, and greater adaptability.

Killer Generator

The killer generator is a small a-c, magneto type generator. It has a permanent magnet armature mounted on the amplidyne armature shaft, and small field coils mounted on the amplidyne frame (fig. 3-12).

As the amplidyne shaft rotates, the permanent magnet induces an a-c voltage in the small field coils. This a-c voltage is connected to a demagnetizing winding, which consists of a few turns near the control and compensating windings. The demagnetizing winding carries alternating current, and its rapidly reversing field removes any residual magnetism left by the control or compensating fields when their current goes to zero.



53.46

Figure 3-12. — Complete schematic of the amplidyne.

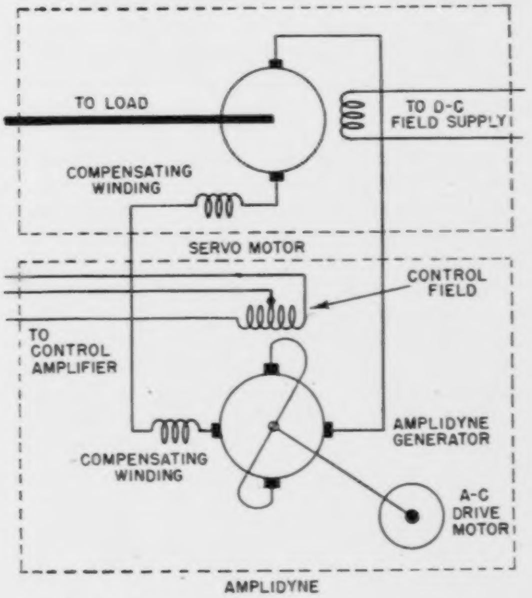
Quadrature Field Winding

The quadrature field winding is wound on the amplidyne frame at right angles to the control winding. This means that the quadrature winding is in the same plane as the quadrature field established by armature current. If the quadrature field's strength is steady, the quadrature flux threads through the quadrature winding without inducing a voltage in it. There will be no induced voltage in the quadrature winding unless the quadrature magnetic field changes in strength. The quadrature field is created by the induced voltage in the armature; hence the induced voltage in the quadrature winding is a direct measurement of the rate of signal change in the control winding. This induced voltage is fed back to the amplifier to reduce overtravel and hunting by the gun mount.

COMPLETE PICTURE

Now we have a complete amplidyne generator as used in the Power Drive Mk 35. Figure 3-13 shows a schematic diagram of the circuits in the generator. The action of the generator can be summarized as follows:

1. A very low power input to the control field creates a large armature current due to



53.47
Figure 3-13.—Basic amplidyne drive.

the shorted brushes, thus producing a relatively strong quadrature or cross field. The armature windings cut the quadrature field, and a large voltage is induced. This voltage is delivered to the load through load brushes.

2. The magnetic field set up in the armature by load current is canceled out by the compensating winding field.

3. Residual magnetism is removed by an a-c magnetogenerator.

4. The control winding is split into two windings wound in opposite directions to give more sensitive control.

Characteristics

Amplidyne generators are driven at relatively high speeds (1800 to 4000 rpm) to reduce their size. They respond quickly to changes in control field current. The delay between a change in the magnitude of the control field current and the resulting change in load current is about 0.1 second.

A limitation on the size of the amplidyne results from commutation of the self-induced voltage in the coils, and the consequent sparking at the commutator.

An amplidyne generator, in converting mechanical energy into electrical energy, can be compared to a pump, pumping electrons through wires. It forces electrons out through one wire, and pulls them back in through another. This action is similar to that of the A-end pump in a hydraulic drive. The d-c drive motor on the gun mount converts the electrical energy back into mechanical energy. This action is similar to that of the B-end hydraulic motor.

The advantages of the amplidyne drive are:

1. It responds rapidly to small signals.
2. It delivers power smoothly.
3. Being all electrical, it is a very flexible installation.
4. Most of the control equipment can be located below decks.

TRAIN AND ELEVATION DRIVE MOTORS

The train and elevation drive motors are identical. Both are 8.5-hp d-c/ motors with a shunt-compensated winding separately excited. The inputs to the motor are the field excitation current from the motor field control unit in Amplifier Mk 40, and the control current from the amplidyne generator. The control current is applied to the armature of the motor.

The characteristics of a shunt motor are covered in Basic Electricity, NAVPERS 10086, latest revision. Here, only the operational features, plus the reasons for using this type of motor, will be discussed.

The operational features of a shunt motor are that the output torque varies linearly with input current throughout the designed range of input currents. So you can see that if the load is constant and the current is increased, the motor will speed up. The load on the motor is the armament, which has a constant weight. As the control current from the amplidyne increases or decreases, the motor will increase or decrease its speed in proportion. The field excitation remains constant at 1.4 amps, at all times.

Another advantage of the shunt motor is a fairly constant speed under a variable load. When the armament is tracking a target with a constant angular rate, the armament will follow smoothly. If the control current from the amplidyne is constant the armament will move at a constant angular rate until the signal is changed. This is true regardless of the load put on the motor by the angular rate of the armament (provided the load is within the design limits of the motor).

The shunt motor is separately excited. This has two advantages: it makes the motor easy to reverse, and it simplifies speed control. Since the amplidyne is the source of excitation current, we can change the direction of motor rotation by changing the excitation polarity. And we can change the motor speed by an increase or decrease of the amplidyne's current output.

The series compensating winding has the same function here as in the amplidyne generator. Armature reaction is caused by current in the motor armature; but the flux revolves in the opposite direction from that of the generator. The armament reaction is overcome by the compensating field.

The amplidyne generator and the drive motor are not continuous duty devices. They are rated for 1-hour intermittent operation. With intermittent operation, the generator and motor temperatures will not rise beyond acceptable limits. The equipment can produce a large power output for a short period of time.

POWER CONTROL CIRCUITS

Before going into the actual circuitry, we should take a look at the elements employed to get familiar with their functions. Most of the elements are simple devices already familiar to you, and will not require a detailed explanation.

A CIRCUIT BREAKER is a device that opens a circuit while carrying current. It protects the circuit from abnormal conditions, such as low power supply or overload.

A RELAY is an electrically operated device for opening and closing a circuit. A small power source can be used to operate a relay, which in turn connects a large power source to the load. The relay can be operated from a remote station. Relays can control a timed sequence of operations.

An OVERLOAD RELAY is similar to a circuit breaker. It protects the equipment from excessive current by opening the circuit.

INTERLOCK SWITCHES are safety switches connected in series with the starting and holding circuit of the drive, so that the drive cannot be started unless certain conditions exist. These switches are there to protect both personnel and equipment.

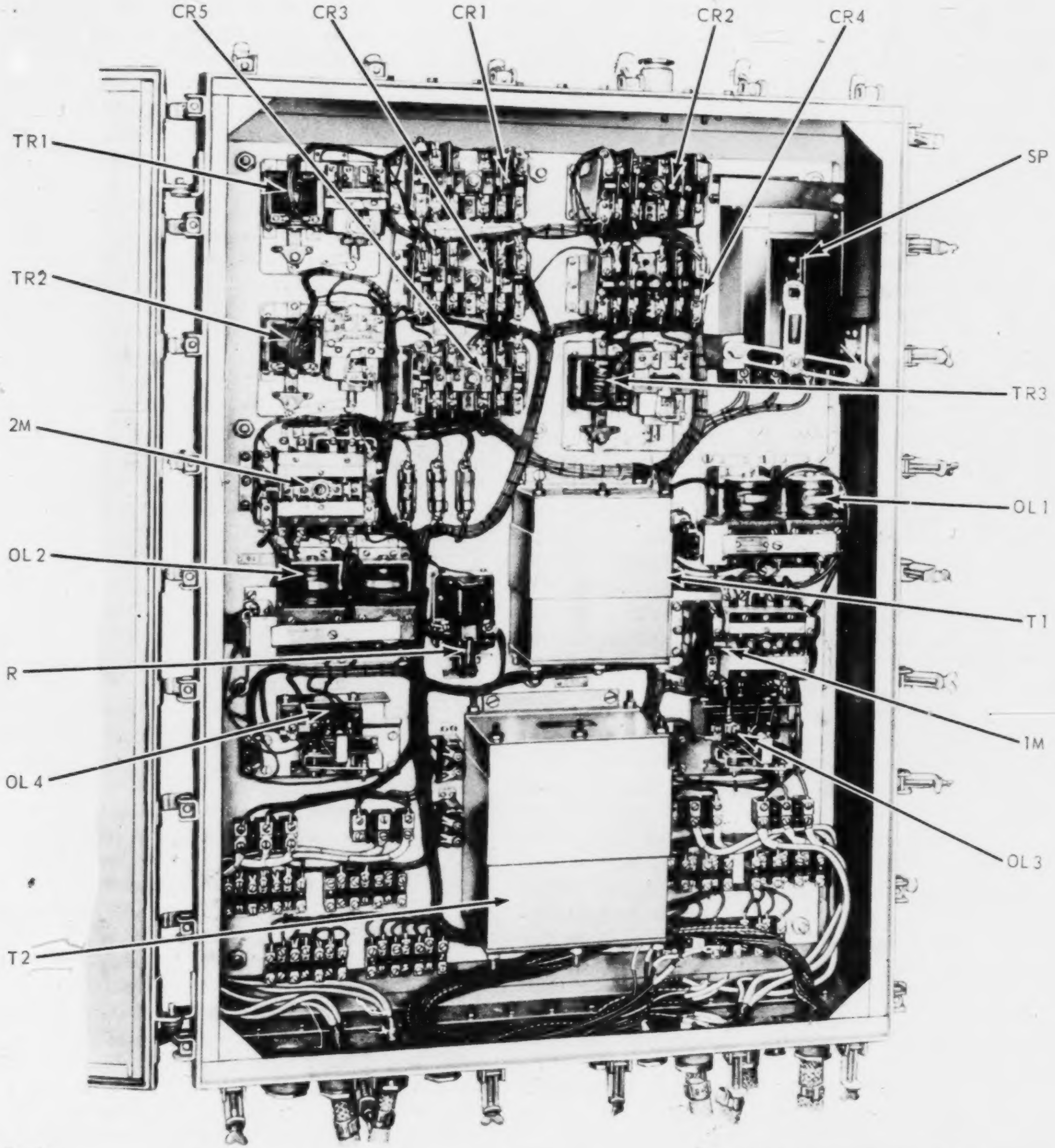
We will use the power control circuits in the Power Drive Mk 35 as an example. Although the circuits of other amplidyne drives may differ in detail, they all operate on the same basic principles.

The electrical supply necessary to operate the power drive is 440-volts 3-phase alternating current, supplied to Control Panel Mk 65 (fig. 3-14). If the armament is to be operated in automatic, a power supply for synchro operation is also required as an input to the control panel. In the control panel, usually mounted below decks, is a circuit breaker which controls the 440-volt supply for both train and elevation. The circuit breaker can be operated by a handle to serve as a main disconnect switch. It also has a thermal overload device, which will open the circuit automatically if the line current becomes excessive.

When the circuit breaker is closed, it energized transformers T1 and T2 (fig. 3-14). Transformer T2 furnishes a 550-volt plate supply for the field control unit of Amplifier Mk 40. Transformer T1 energizes all the filament transformers in Amplifier Mk 40 except those of the parallax amplifier. The parallax amplifier receives its supply from the parallax synchro voltage. (Tubes will have a longer service life if the filaments are energized continuously during periods of anticipated operation. If the filament supply is repeatedly turned on and off, metal fatigue of the tube elements will result. Metal fatigue is the breakdown of the metal structure due to stress. This stress is caused by the extreme temperature changes that occur when the filament circuit is energized and deenergized.) T1 also energizes a blower motor in the amplifier housing and provides a source of 115-volt alternating current for the power control circuit.

Before the amplidyne can be started, the interlock switches for both train and elevation must be closed. These switches are in series with the power supplies. They are safety devices, and should never be bypassed (shorted out) or tampered with. You will find them associated with the armament securing devices, brakes and manual drive mechanisms. Interlock switches are often used in electrical and electronic equipment, so that opening the cover or door will operate the switches and open the high voltage circuits.

The overload relays must be in the operating position with their contacts closed. There are



Symbol	Name	Legend		SP	AIR CIRCUIT BREAKER
TR1	TIMING RELAY			TR3	TRAIN TIMING RELAY
TR2	ELEVATION TIMING RELAY	CR1	CONTROL RELAY	OL1	TRAIN OVERLOAD RELAY
2M	ELEVATION LINE CONTACTOR	CR2	CONTROL RELAY	1M	TRAIN LINE CONTACTOR
OL2	ELEVATION OVERLOAD RELAY	CR3	CONTROL RELAY	OL3	TRAIN OVERLOAD RELAY
R	RELAY ELEVATION	CR4	CONTROL RELAY	T1	CONTROL TRANSFORMER
OL4	ELEVATION OVERLOAD RELAY	CR5	CONTROL RELAY	T2	PLATE SUPPLY TRANSFORMER

Figure 3-14.—Control Panel Mk 65 Mod 0, cover open. 53.48

four thermally operated overload relays in this power drive. They protect the train and elevation drive motors and the amplidyne generators. If one of the relays should be tripped, it would deenergize the field supply of both the generators and the motors.

Motor Start Switches

For gun mount operation a control selector switch (SMI) on the gun control panel must be in one of the local positions before starting the gun mount's amplidyne motors. This is to keep the mount drive in local control until its operation has been tested.

For launcher operation a control selector switch (SMI) on the launcher control panel (LCP) can be in either the local or remote position before starting the launcher amplidyne motors. The purpose of SMI is to allow the launcher power drives to be started from either the LCP or Fire Control Panel (FCP). The FCP is located in a remote fire control station and contains switches for starting the launcher power drives. This is done by pressing a launcher drive start switch (SM2) when control switch SMI on the LCP is in the remote position.

Figure 3-15 shows the circuit ready for the first sequence of operation when in local control. All that remains to be done is to push a start button on either the gun control panel (GCP) or launcher control panel(LCP).

Before we study the operation of these control circuits let's take up some of the differences between the features of the launcher drive and the gun mount drive. These differences are pointed out in figure 3-15. The controls in the A portion of the figure are those associated with launcher application of the Mk 35 power drive while the controls in the B section are used with gun mounts.

There is no major difference in the Mk 65 control panel. Only the way in which it connects to the system.

When used as part of a launcher drive, the Mk 65 control panel is connected to both the Launcher Control Panel (LCP) and Fire Control Panel (FCP). The 115 volt output of T1 is routed from the AC connection through relay coils R and 1M, through the overloads and interlocks to SM4 on the LCP.

The common side of T1 (ACC) is routed from terminal 5 in the Mk 65 control panel to SM1 on the LCP. Another ACC connection exists from ACC of T1 through the top contacts of 1M, through the contacts of R to terminal 9. From terminal 9 ACC is routed to SM3 on the LCP and SM2 and SM5 on the FCP.

When used as a part of a gun mount drive, the connections to the LCP and FCP would not be made. Instead the ACC line at terminal 5 in the Mk 65 control panel would be tied to SM1 of the gun control panel, and terminal 9 in the Mk 65 control panel would be tied to start switch SM3.

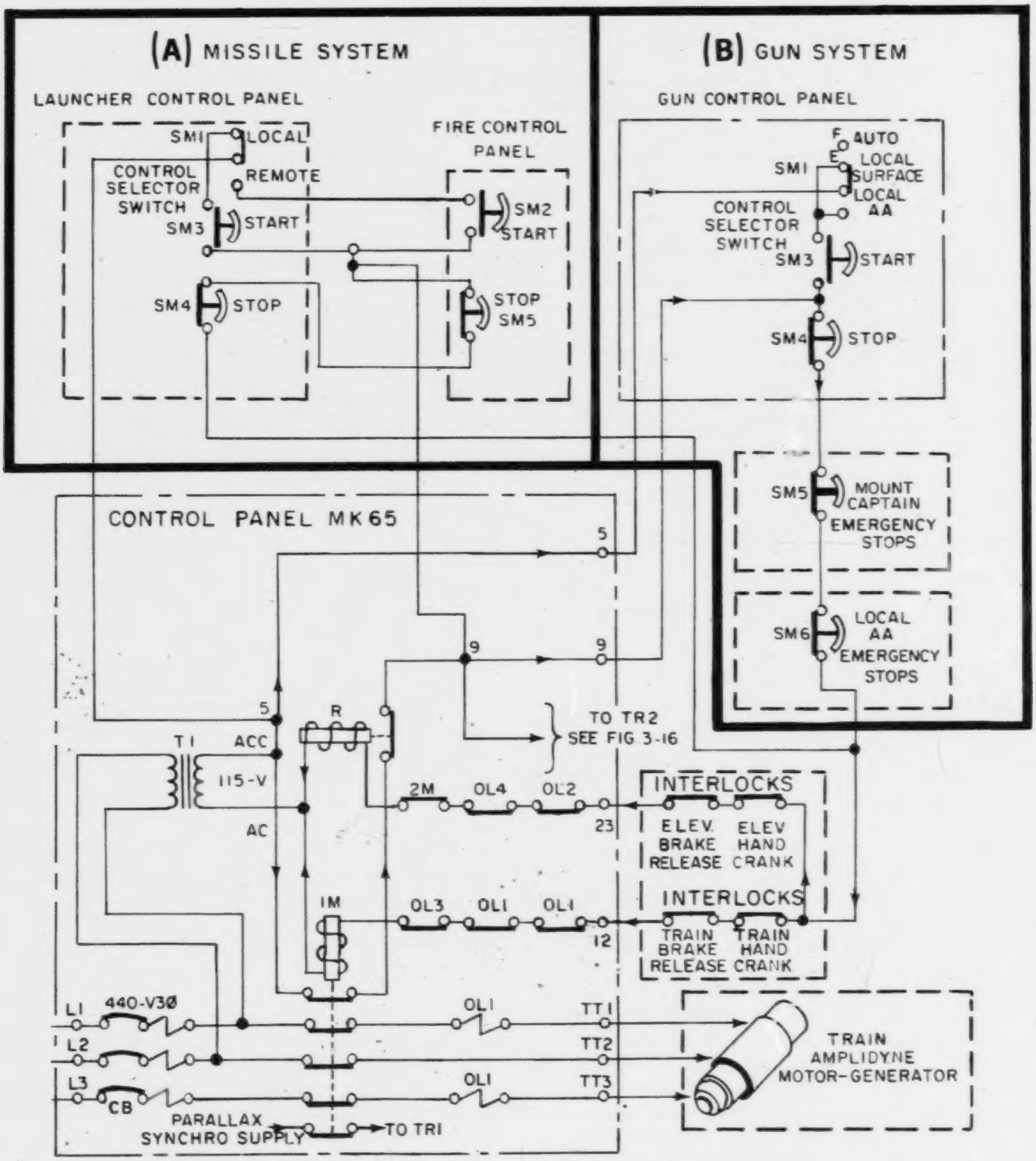
The AC line would still go from T1 through the coils of relays R and 1M through the overloads and interlocks to the emergency stop switches SM4, SM5 and SM6. Notice that the interlocks and overloads (OL) are in series with the relay coils. When SM3 is pressed, the relay coils of 1M, R, and TR2 are energized, and their contacts close. 1M completes the circuit to the train amplidyne generator's motor. The auxiliary relay (R) completes the circuit that connects the ACC side of the line to a point between the START and STOP buttons. This shorts out the START button, so that it can be released. Relay R also completes the circuit to time delay relay TR2.

The contacts of TR2 are in series with the coil of relay 2M, as you can see in figure 3-16. Therefore relay 2M can not operate until relay TR2 has operated. TR2 has a time delay device of the "definite-time" type. It is operated by a solenoid which compresses a metal bellows. The air trapped in the bellows escapes gradually through a needle valve, which can be adjusted to determine the length of the time delay.

Time delay TR2 is set at 8 seconds, to give the train amplidyne time to reach operating speed. From your study of motors, you will remember that there is a large starting current in all motors. The overload is present until a counterelectromotive force is built up in the armature of the motor. The delay provided by TR2 ensures that the overloads caused by starting the train and elevation amplidyne generator motors will not be present simultaneously.

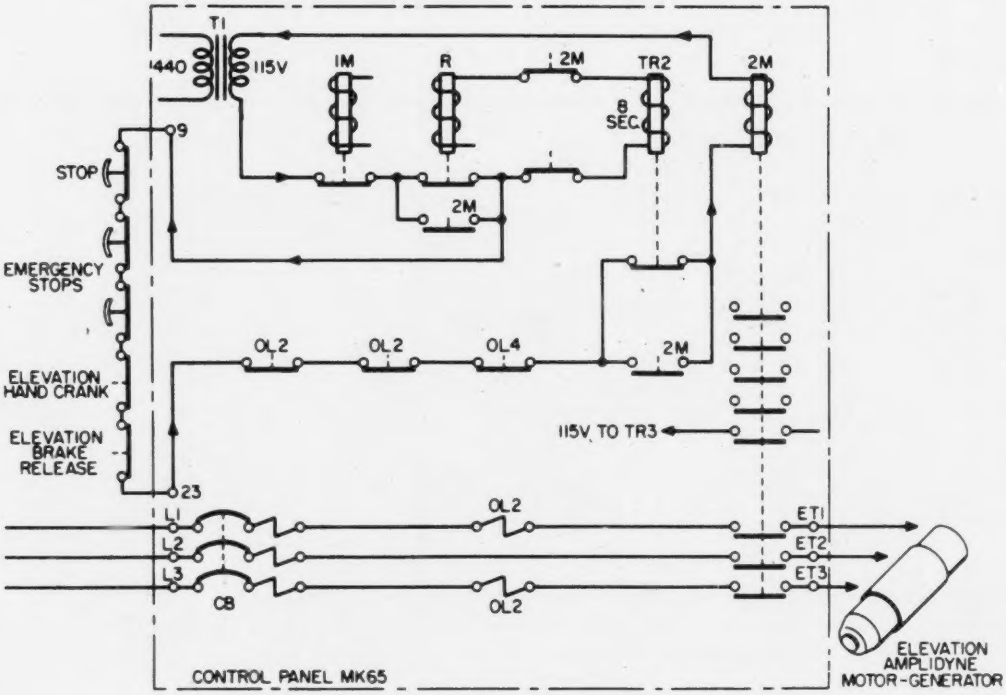
When TR2 picks up at the end of 8 seconds, elevation line contactor 2M is actuated to start the elevation amplidyne. Contactor 2M, when closed, short-circuits the contacts of R and TR2, and deenergizes the coils of both of these relays. Thus the circuits set up by R and TR2 are maintained, although the relays are permitted to drop out.

Another contact on 2M energizes the coil of timing relay TR3 (fig. 3-17). TR3 operates after 8 seconds, which gives the elevation amplidyne time to come up to speed, and the cathodes of the thyratron tubes in the motor field control


(A) MISSILE SYSTEM
LAUNCHER CONTROL PANEL
SM1
LOCAL
REMOTE
CONTROL SELECTOR SWITCH
SM3
START
SM4
STOP
FIRE CONTROL PANEL
SM2
START
STOP
SM5
(B) GUN SYSTEM
GUN CONTROL PANEL
F
AUTO
E
SM1
LOCAL SURFACE
LOCAL AA
CONTROL SELECTOR SWITCH
SM3
START
SM4
STOP
SM5
MOUNT CAPTAIN EMERGENCY STOPS
SM6
LOCAL AA EMERGENCY STOPS
CONTROL PANEL MK 65
5
9
9
5
R
TO TR2 SEE FIG 3-16
T1
ACC
115-V
AC
2M
OL4
OL2
23
INTERLOCKS
ELEV. BRAKE RELEASE
ELEV HAND CRANK
1M
OL3
OL1
OL1
12
INTERLOCKS
TRAIN BRAKE RELEASE
TRAIN HAND CRANK
L1
440-V3Ø
L2
L3
CB
OL1
OL1
TT1
TT2
TT3
TRAIN AMPLIDYNE MOTOR-GENERATOR
PARALLAX SYNCHRO SUPPLY
TO TR1

53.49(53C)

Figure 3-15.—Relay circuits R and 1M.



53.50
Figure 3-16.—Relay circuit 2M.

unit time to warm up. Operation of TR3 energizes the coil of control relay CR4, whose contacts maintain the circuit through its own coil, and open the circuit through the coil of TR3. CR4 controls the plate supply for the control fields of the train and elevation amplidynes, and completes the field circuits for the train and elevation drive motors. CR4, when operated, also energizes the coil of brake release relay CR5. When energized, this relay supplies 440 volts to release the magnetic brakes in both the train and elevation systems. To energize CR5, it is necessary that control relay CR4 and loss-of-field relays K301 and K302 also be energized. In addition, the safety switches on the appropriate one-man control must be closed when in local control. Both synchro supply relays CR1 and CR2 must be energized when in automatic control. The coils of CR1 and CR2 are energized by the elevation and train synchro reference supply. The loss-of-field relays are energized by the current that supplies the field of the train and elevation drive motors.

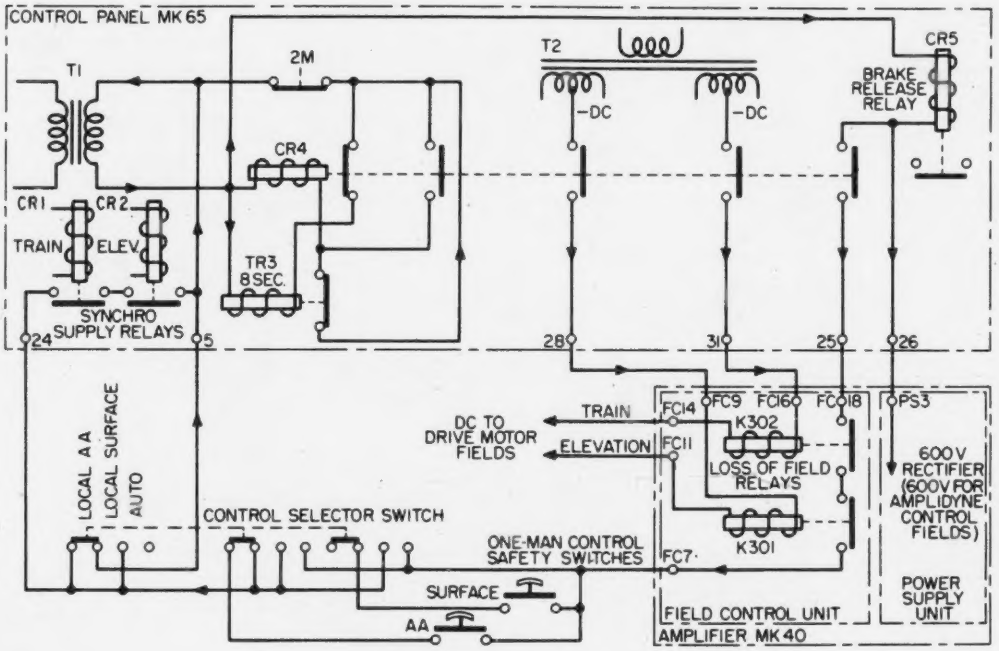
Thus, before the train and elevation brakes can release, two things must happen. First, the fields of the train and elevation drive motors must be energized. Second, the train and elevation synchro circuits must be energized (if in automatic control), or the proper safety switch must be closed (if in local control.)

When the circuit to CR5 is completed, the 600-volt section of the power supply unit will also be energized. This section supplied 600 volts direct current to the train and elevation amplidyne control field circuits.

Launcher Start Circuit

The circuit to CR5 differs in the GMLS in that the power off brakes are released only when start-safe operate switch SMC1 on the LCP is positioned to operate or when local remote select switch SM1 also located on the LCP is positioned to remote, figure 3-18.

The purpose of SMC1, when in the safe-start position, is to prevent the power-off brakes from


CONTROL PANEL MK 65
T1
2M
T2
CR5
BRAKE RELEASE RELAY
-DC
-DC
CR4
CR1
CR2
TRAIN
ELEV.
TR3
8 SEC.
SYNCHRO SUPPLY RELAYS
24
5
28
31
25
26
LOCAL AA
LOCAL SURFACE
AUTO
CONTROL SELECTOR SWITCH
DC TO DRIVE MOTOR FIELDS
TRAIN
ELEVATION
FC14
FC9
FC16
FC18
PS3
FC11
K302
LOSS OF FIELD RELAYS
K301
600 V RECTIFIER (600V FOR AMPLIDYNE CONTROL FIELDS)
ONE-MAN CONTROL SAFETY SWITCHES
FC7
SURFACE
AA
FIELD CONTROL UNIT
POWER SUPPLY UNIT
AMPLIFIER MK 40

53.51
Figure 3-17.—Relay circuits CR4, TR3 and CR5.

being released until a train warning signal has been sounded and an all clear report has been issued by a safety observer when moving the launcher in local control. In addition, when SMC1 is positioned to operate and the launcher area safety switch SMX1 is plugged into the circuit, it acts as a safety for the LCP operator. Safety switch SMX1 is used when personnel are performing maintenance or test on the launcher. A safety key on SMX1 must be depressed to release both the train and elevation power-off brakes.

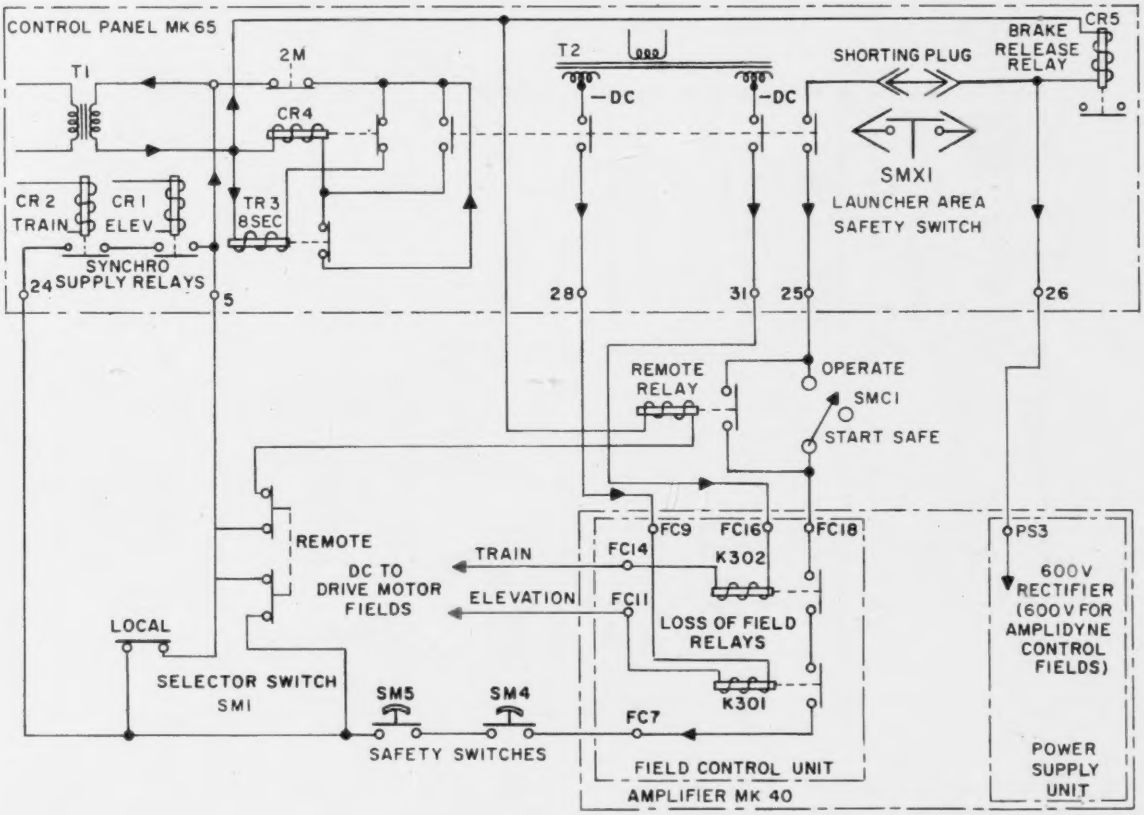
Warning: Ensure that the launcher area is clear of personnel before closing launcher area safety switch SMX1. Launcher runaway in train or elevation could result in injury or death to personnel.

When the launcher is in remote control mode (SM1 positioned to remote), the circuit to CR5 is completed to allow the power-off brakes to be released so that the launcher can automatically train in the proper direction to return to its stow position. This automatic operation prevents the launcher from training away from the zero cable twist position and prevents the launcher from being stowed with 360 degrees of cable twist. The zero cable twist position assembly controls the launcher power drives, when operating in remote mode, to position the launcher at stow when the launcher is not assigned to a fire control system. When the launcher is assigned to a fire control system, it responds to orders to aim and launch missiles. The remote-assigned mode is the only mode of operation in which missiles can be fired.

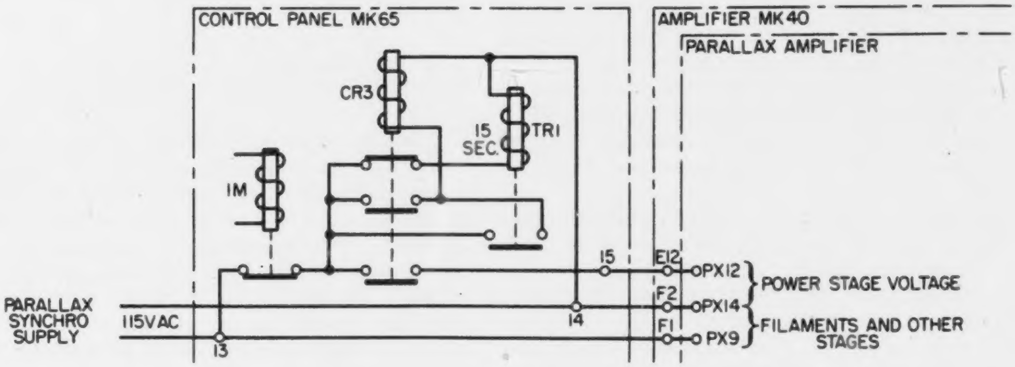
Parallax Amplifier Power Supply Circuit

Recall from your study of parallax in GMG 3/2 that the purpose of a parallax correction system is to introduce parallax corrections in train to compensate for the actual base length between the gun director and gun mount. This is accomplished by a parallax motor, parallax change gears, and a parallax amplifier. Supply for the power stage of the parallax amplifier goes through the contacts of relay's 1M and CR-3 figure 3-19.

When line contactor 1M operates to start the train amplidyne its contacts also energize timing


CONTROL PANEL MK 65
T1
2M
CR4
CR 2
TRAIN
CR 1
ELEV
TR 3
8 SEC
SYNCHRO
SUPPLY RELAYS
24
5
T2
-DC
-DC
SHORTING PLUG
BRAKE
RELEASE
RELAY
CR5
SMX1
LAUNCHER AREA
SAFETY SWITCH
28
31
25
26
REMOTE
RELAY
OPERATE
SMC1
START SAFE
REMOTE
TRAIN
DC TO
DRIVE MOTOR
FIELDS
ELEVATION
FC9
FC16
FC18
FC14
K302
FC11
LOSS OF FIELD
RELAYS
K301
FC7
LOCAL
SELECTOR SWITCH
SM1
SM5
SM4
SAFETY SWITCHES
FIELD CONTROL UNIT
AMPLIFIER MK 40
PS3
600V
RECTIFIER
(600V FOR
AMPLIDYNE
CONTROL
FIELDS)
POWER
SUPPLY
UNIT

53.269
Figure 3-18.—Brake Release Circuit.


CONTROL PANEL MK65
AMPLIFIER MK40
PARALLAX AMPLIFIER
CR3
15
SEC.
TR1
1M
15
E12
PX12
POWER STAGE VOLTAGE
PARALLAX
SYNCHRO
SUPPLY
115VAC
14
F2
PX14
F1
PX9
FILAMENTS AND OTHER
STAGES
13

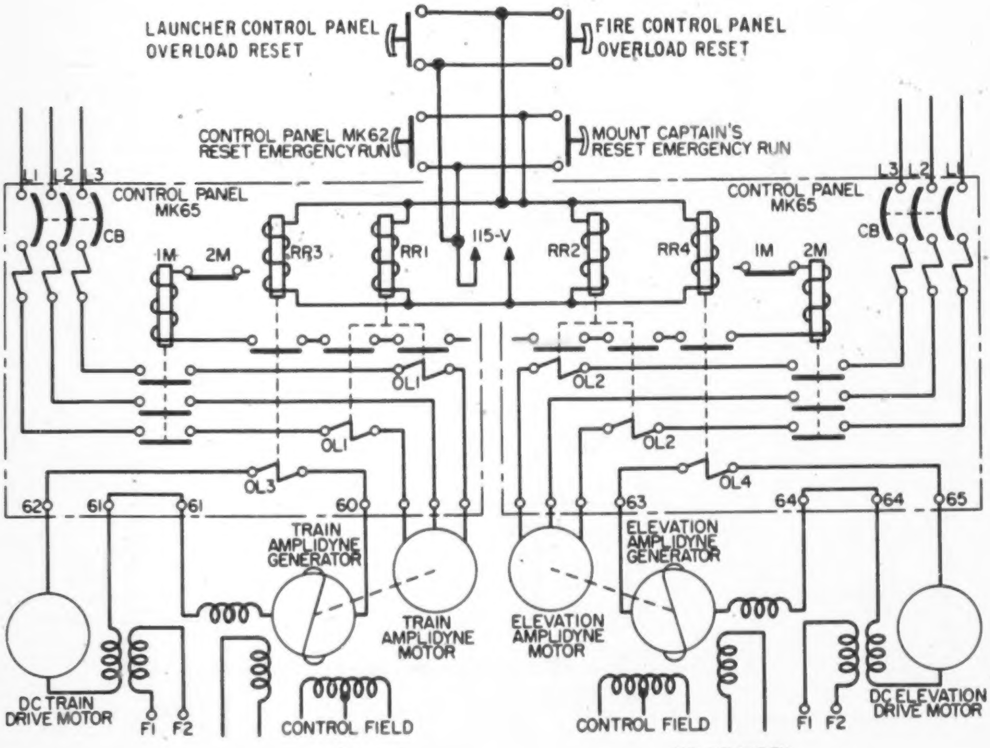
53.52
Figure 3-19.—Relay circuit CR3.

relay TR1 in the parallax control circuit. After 17 seconds, TR1 will pick up and energize CR3 to complete the power circuit. This delay provides enough time to heat the cathodes of the power tubes in the parallax amplifier. Other contacts of CR3 bypass the contacts of TR1, and break the TR1 holding circuit. If the supply voltage fails or 1M releases to shut down the equipment, the power circuit cannot be restored without again going through the timing cycle of relay TR1.

In the BPDMS train and elevation parallax corrections are computed during system alignment. Adjustments are made to the train and elevation transmitters located in the missile directors, and the corrected parallax information is sent to the launcher as part of launcher position orders. No parallax motor, parallax change gears, or parallax amplifier are used with the BPDMS.

OVERLOAD PROTECTION CIRCUITS

Overload protection for the control circuits is provided by the circuit breaker and the four overload relays. When one of the overload relays drops out, it may be reset electrically by pressing either of the RESET EMER RUN buttons. These buttons are located on the gun control panel and mount captain's panel for gun mount operation and on the LCP and FCP for missile launcher operation (fig 3-20). If you want to resume power operation immediately after an overload you will have to hold the reset emergency run button down while pressing down the start button for sixteen (16) seconds delay. Then release the start button and continue holding down the emergency run button. This is necessary because the overload relays contain a thermal device that must cool off before the overload contacts will stay closed. Operating the power


LAUNCHER CONTROL PANEL OVERLOAD RESET
FIRE CONTROL PANEL OVERLOAD RESET
CONTROL PANEL MK62 RESET EMERGENCY RUN
MOUNT CAPTAIN'S RESET EMERGENCY RUN
L1 L2 L3
CONTROL PANEL MK65
CB
1M
2M
RR3
RR1
115-V
RR2
RR4
CONTROL PANEL MK65
L3 L2 L1
CB
1M
2M
OL1
OL2
OL1
OL2
OL3
OL4
62
61
61
60
63
64
64
65
TRAIN AMPLIDYNE GENERATOR
TRAIN AMPLIDYNE MOTOR
ELEVATION AMPLIDYNE GENERATOR
ELEVATION AMPLIDYNE MOTOR
DC TRAIN DRIVE MOTOR
F1 F2
CONTROL FIELD
CONTROL FIELD
F1 F2
DC ELEVATION DRIVE MOTOR

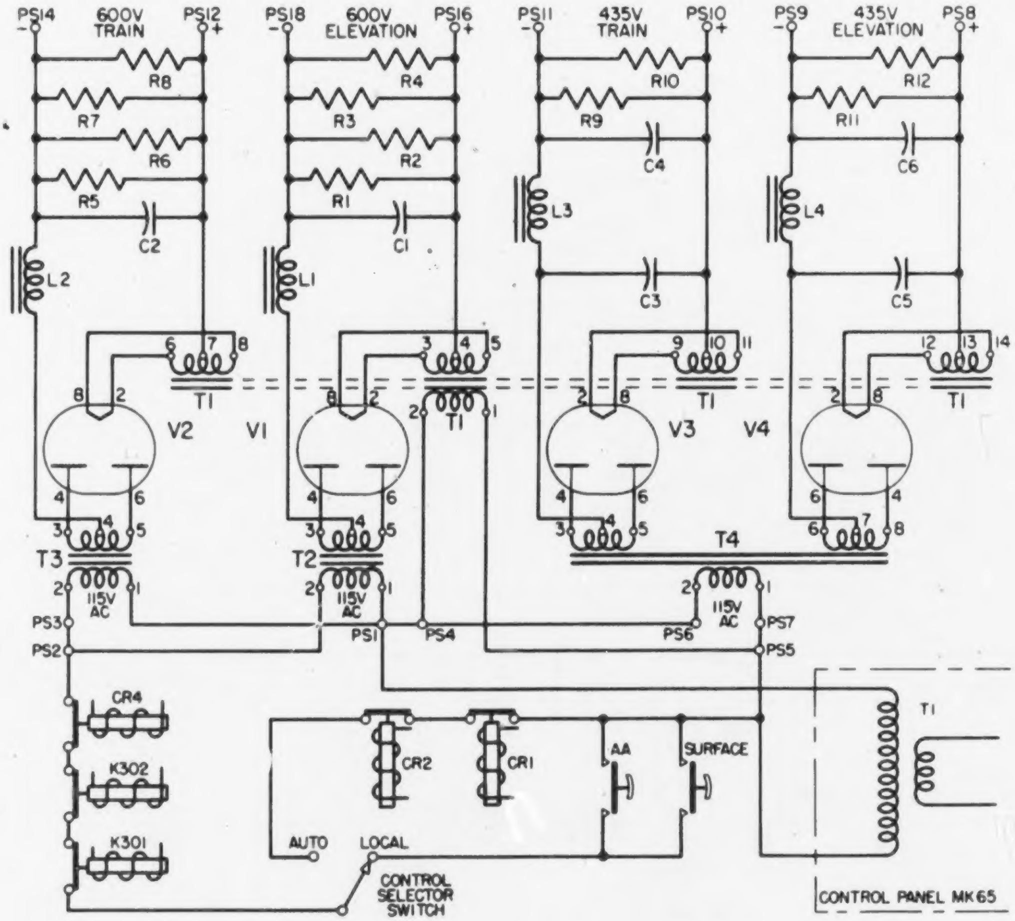
53.53(53C)

Figure 3-20.—Overload relays and reset circuits.

drive with this button depressed bypasses the protective function of the overload relays. The reset relays (RR1, 2, 3, and 4) are energized by the RESET EMER RUN buttons, and hold the overload contacts in the closed position. You should therefore use this method of operation only in extreme emergencies. When an overload relay has been actuated, the cause of the overload should be investigated and corrected before trying to resume power operation.

POWER SUPPLY UNIT

The d-c power supply unit consists of rectifiers providing d-c power at 435 and 600 volts (fig. 3-21) to the train and elevation amplifiers. Plate supplies for the 435-volt rectifiers are taken from transformer T4, fed by T1 in Control Panel Mk 65, which also furnishes filament power. For local operation the plate voltages for the 600-volt rectifier are taken from T1, through T2 and T3, via contacts of relays CR4, K302, K301, one of the safety switches, and the control selector switch. For automatic operation, the plate voltage circuit for the 600-volt rectifier must be completed through contacts of synchro supply relays CR1 and CR2. If the elevation or train synchro supply fails, CR1 or CR2 will open and deenergize the supply for the 600-volt rectifier. Relays K301 and K302 will also


PS14
600V TRAIN
PS12
PS18
600V ELEVATION
PS16
PS11
435V TRAIN
PS10
PS9
435V ELEVATION
PS8
R8
R7
R6
R5
C2
L2
R4
R3
R2
R1
C1
L1
R10
R9
C4
L3
C3
R12
R11
C6
L4
C5
T1
V2
V1
V3
V4
T3
T2
T4
115V AC
PS3
PS2
PS1
PS4
PS6
PS7
PS5
CR4
K302
K301
CR2
CR1
AA
SURFACE
AUTO
LOCAL
CONTROL SELECTOR SWITCH
CONTROL PANEL MK65

53.54
Figure 3-21.—Power supply unit.

deenergize this supply if either drive motor field loses excitation.

Since the rectified voltages supply plate voltage for the train and elevation amplifiers, which in turn supply control field current for the amplidynes, the circuit just described must be completed before the amplidynes can be excited. The same circuit also energizes brake release relay CR5.

SAFETY

Much has been written on the subject of safety. Sources of information about this subject can be found throughout this text. Details on safety pertaining to amplidyne power drives are found in individual OPs.

In general, the safety procedures and precautions outlined in chapter 9 Test Equipment, are applicable to amplidyne drives. In that chapter you will learn that safety is best practiced when incorporated into your working habits. In this way it will become second nature to you.

To be more specific, the following precautions should be observed while maintaining amplidyne equipment.

1. Be alert for the presence of high voltages (440 and 600 volts) which are exposed whenever covers of equipment panels, controllers, or amplifiers are removed.

2. Never remove or bypass any safety interlocks while operating the mount under power.

3. Some mounts equipped with amplidyne drives are constructed with a radar antenna as an integral part of the mount. Never work in the path of the radar antenna unless it is secured.

4. If controlling the mount from a remote station, make sure that the mount is attended by someone, and that there is communication between the two stations.

5. The 3'' gun, which we have used for illustrative purposes in this chapter, is breech heavy. This means that, without engaging the elevation securing pins, a malfunction of the elevation brake can cause the gun to settle at the rear. Anything in its path as it slams into its elevation positive stops will be damaged.

6. Do not use electrical test equipment known to be unsafe.

7. When working with electrical circuits, take your time. No job is so urgent that you cannot take time to be safe.

CHAPTER 4

AMPLIDYNE CONTROL EQUIPMENT

In the preceding chapter we discussed the basic principles of amplidyne power drives, and the function of their major components. In this chapter we will take up the devices and circuits which control power drives.

To understand this chapter, you must know something about electronics. We will assume that you have read the chapters on vacuum tubes and amplifiers in Basic Electronics, NavPers 10087. We can give you only a quick review here.

ELECTRON FLOW is caused by a difference in potential; electrons will flow to equalize two different energy levels. Electrons flow from negative to positive, or from negative to less negative, or from positive to more positive.

A CAPACITOR, when charged, stores electrical energy. Under some conditions a capacitor tends to oppose any change of VOLTAGE in the circuit. Electrons cannot flow through a capacitor; but they can flow into it or out of it, and thus produce a charge on its plates. Capacitors block the flow of direct current, but pass alternating current. They take time to charge and discharge; the length of time depends on both the size of the capacitor and the amount of resistance in the circuit.

Capacitors are used as filters, to oppose changes in voltage, and to smooth out the voltage ripple in power supplies. They are used as couplers, to pass alternating current or pulses while blocking direct current.

INDUCTORS oppose changes in the CURRENT through a circuit. The choke coils illustrated in this chapter are inductors. An inductor offers a relatively high resistance to alternating current, and a relatively low resistance to direct current.

ELECTRON TUBES

An ELECTRON TUBE controls the flow of electrons, much as a valve in a hydraulic power drive controls the flow of fluid.

Elements of a Tube

The CATHODE emits electrons into the area around it, creating a space charge. When the cathode is heated, its electrons speed up until some of them escape from the cathode material. This process is called thermionic emission. When a heated cathode is to be used as an emitter, the air must be removed from the tube envelope, or enclosure, to keep the cathode from burning up, and to permit a steady flow of electrons through the tube.

The PLATE (anode) of the tube attracts electrons from the cathode's space charge. Vacuum tube circuits are so designed that the plate has a positive potential with respect to the cathode.

The GRID is a third electrode, mounted between the cathode and the plate. The voltage applied to the grid controls the flow of electrons through the tube.

Diode Tubes

A diode has only two electrodes—cathode and plate. Since current can flow in only one direction—from cathode to plate—the diode serves as a rectifier. If you apply alternating current to a diode, current will flow only when the plate is positive; on the other half cycle, when the plate is negative, the tube is an open circuit. Thus a single diode can be used as a half-wave rectifier. For full-wave rectification, we need two diodes.

Figure 4-1 shows a twin diode tube, which consists of two diodes in the same envelope. The circuit illustrated is a part of the power supply unit of the Mk 35 power drive; it furnishes the plate supply voltage for the elevation amplifier.

115 volts alternating current is supplied to transformers T1 and T2. T1 supplies filament heater voltage to the tube, while T2 supplies plate voltage. The two plates are connected to

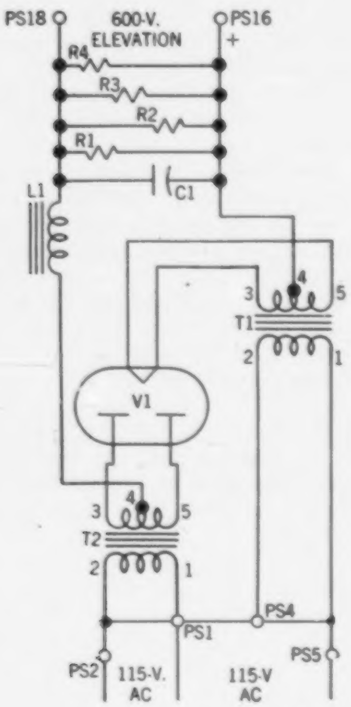


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Figure 4-1.—Power supply unit.

opposite ends of T2. Thus when the alternating current flows in one direction, one plate will be positive; when the current changes direction, the other plate becomes positive. Within the tube, current will flow from the cathode to whichever plate is positive. From the plates, current flows through the secondary of T2 to the center tap (number 4).

Output current flows from the tube in only one direction, in spite of alternations of the a-c supply. You may wonder what keeps the output current from rippling (rising and falling) as the two plates alternately pass current. The ripple is removed by the action of the choke coil, L1, and the capacitor, C1.

L1, the choke coil, is a filtering device which opposes any change in CURRENT. It passes direct current with little resistance, but shows a high resistance to the ripple current. A choke coil gives good current regulation.

When the tube begins to pass current, C1 starts to charge. When current through one plate of the tube starts to decline, C1 will discharge in opposition to the reduction of potential. Before it can discharge completely, the other plate conducts and the capacitor charges again. This action continues until the capacitor is at almost the full voltage of the positive pulses from the plates. The capacitor acts as a reservoir which will discharge into the load when the voltage decreases. These actions smooth out ripple in the d-c output.

The load on the rectifier is not shown in figure 4-1. Actually, it is the plate circuits of the last stage of amplification in the elevation amplifier. Resistors R1, 2, 3, and 4 are in parallel with the load, and help to compensate for variations in load demand on the rectifier.

To complete the circuit, we go out on PS18 to the amplifier, through its tubes, back on PS16 to center tap number 4 in the secondary of T1, and then back to the cathode.

Triode Tubes

The triode tube has three electrodes—plate, cathode, and grid. The grid is an open mesh of fine wire between the plate and the cathode. Electrons flow through it with little interference. The potential on the grid controls the electron flow through the tube. Grid potential is measured with respect to cathode potential and is called BIAS.

A highly negative bias will cut off the current flow entirely. As the grid bias becomes less negative, current flow increases, and approaches a maximum when the grid potential is the same as that of the cathode. Because a small change in grid voltage causes a large change in plate current, the triode vacuum tube can be used as an AMPLIFIER. We use triode amplifiers in power drive control circuits to operate relays, and to amplify weak gun order signals.

GUN MOUNT CONTROL CIRCUITS

As an example of gun mount control circuits, we have chosen those of the Mk 35 amplidyne power drive. You studied the function of this power drive in chapter 3. Since the synchro and amplifier circuits for train and elevation are practically identical, we will discuss only the train control circuits here.

From chapter 3 you learned that, in automatic control, synchro control transformers in the receiver regulator compare the actual train angle of the mount with the train order from the remote control station. If there is a difference between the two, the control transformers will generate an a-c error signal, and transmit it to the amplifier. The phase of this error signal indicates the direction of the error, and its voltage indicates the amount of error.

In local control, the a-c error signal is generated by an unbalanced bridge circuit in the one-man control unit. We will discuss this in more detail later.

The reference voltage with which the error signal voltage is compared in the amplifier is 115 volts alternating current. In automatic control it is obtained from the synchro supply. In local control it is obtained from transformer T1 in the Mk 65 control panel.

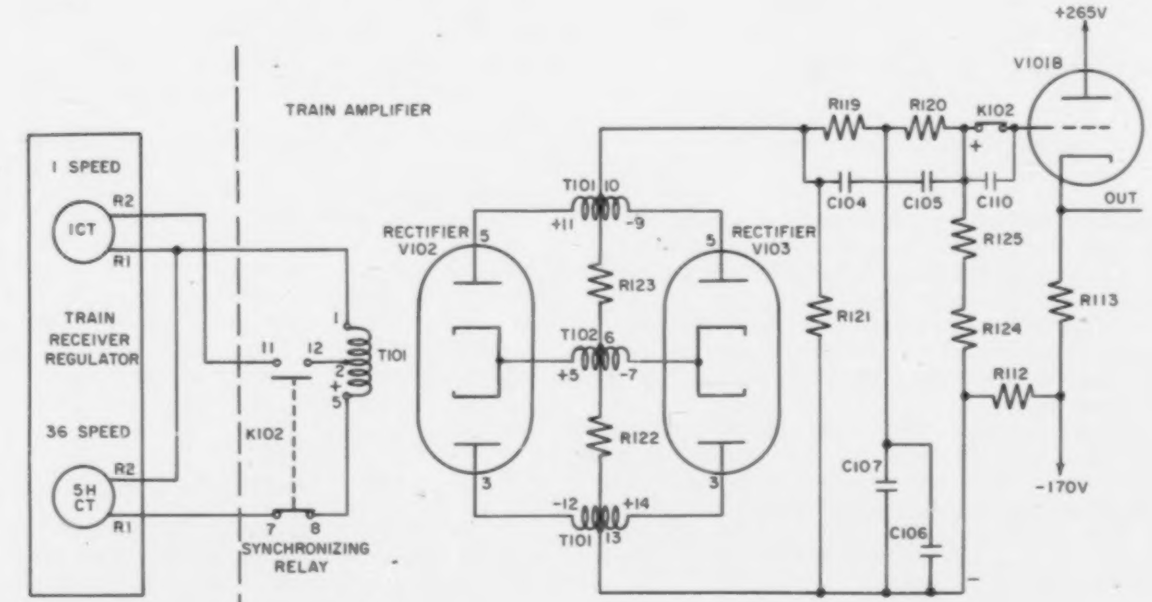
THE TRAIN AMPLIFIER

The train amplifier receives a low power error signal from the gun order transmission system, or from the one-man control station, depending on whether the mount is in automatic or local control. It supplies two control field currents for the amplidyne generator.

In the first of the three stages of the amplifier, the signal is rectified—that is, changed from alternating current to direct current. The amplifier then determines the direction of the ordered movement from the direction of current flow. In the second stage the signal voltage is amplified. In the third stage the signal power is amplified. The output from the third stage is fed directly to the control winding of the amplidyne generator.

Function of the First Stage

The first stage of the train amplifier is illustrated in figure 4-2. At the left of the figure are the sources of signal and reference voltage. You can see that we are receiving


TRAIN AMPLIFIER
I SPEED
ICT
R2
R1
TRAIN RECEIVER REGULATOR
36 SPEED
5H CT
R2
R1
11
12
K102
7
8
SYNCHRONIZING RELAY
T101
1
2
+
5
TRAIN REFERENCE
T102
1
2
RECTIFIER V102
5
3
T101 10
+11
-9
R123
T102 6
+5
-7
R122
-12
+14
T101 13
RECTIFIER V103
5
3
R121
C107
C106
R119
R120
K102
+
C104
C105
C110
R125
R124
R112
+265V
V101B
OUT
R113
-170V

53.56

Figure 4-2.—First stage train amplifier, simplified schematic.

signal voltage through K102 from the 36-speed control transformer in the receiver regulator. From this you know that we are in automatic fine control. The signal current flows from transformer T101 through tubes V102 and V103. It is coupled to the second stage through V101B.

V102 and V103 are duodiodes, used to rectify the signal and compare it with the reference voltage. The a-c signal voltage supplies plate voltage to both tubes through T101.

The end taps of the secondary windings of T101 are connected to the plates of rectifier tubes V102 and V103. The cathode potentials are determined by the a-c reference voltage through T102. The cathodes of V102 and V103 are connected to the end taps of the secondary transformer T102, whose primary receives the 115 VAC reference voltages which also energize the rotor of the 36-speed synchro transmitter in the fire control system.

The reference voltage determines which of the rectifier tubes will pass current during any given half-cycle. Simultaneously, the error-signal voltage determines which half of the firing tube will pass the greater current.

Plus and minus signs at transformer T102 indicate the polarities for one half-cycle. Because the cathodes of V103 are connected to a negative transformer tap (-7), they are negative with respect to the plates, and V103 therefore draws current. Current will flow only from negative to positive, or from negative to less negative. The cathodes of V102 are connected to positive taps, and V102 is dead and cannot conduct because its cathodes are positive. On the opposite half cycle the conditions are reversed; V102 draws current and V103 is dead. When the mount is in correspondence with the 36-speed signal, there is no error signal voltage and both plates of the firing tube V103 have the same potential. The two plates then draw equal currents, the upper plate through R123 and the lower plate through R122. Since current flow is in opposite directions in the two resistors, the voltage drop in one cancels the voltage drop in the other and the net voltage difference across resistors R122 and R123 is zero. This voltage difference constitutes the output of the first stage which is applied through filter resistors R119 and R120 across R125 and R124 in the grid circuit of cathode follower V101B. Thus, for zero error signal, the output of the first stage is zero.

Right Train Signal

An error signal calling for right train affects the polarity of the taps of T101, as indicated by the plus and minus signs (fig. 4-2) for the half-cycle in which V103 is firing. Plus and minus signs at the taps of T102 show reference voltage polarities for the same half-cycle. The right train signal changes the potential of the upper plate (5) of the firing tube V103 in the negative direction, and the tube therefore draws less current through resistor R123. The lower plate (3) voltage changes in the positive direction, and current in R122 is increased. The voltage drop in R122 is now greater than in R123, and the upper end of R123 becomes positive with respect to the lower end of R122. This potential difference will appear across R124 and R125 and have the same polarity. The result of a right train signal is to change the grid voltage of tube V101B in the positive direction.

For the second half cycle, all a-c polarities in T101 and T102 are reversed, and V102 becomes the firing tube. For a right train signal, the upper plate (5) of V102, being connected to a minus tap of T102, draws a light current through R123; and its lower plate (3), connected to a positive tap, draws a heavy current through R122. Thus, the result of a right-train signal is the same for both half cycles, a positive input to the grid of tube V101B.

Left Train Signal

For a left train error signal, polarities in T101 are reversed from those shown in figure 4-2, while those in T102 remain the same. Because the changes in plate voltages have the opposite strengths, the upper plate (5) of V103, draws heavy current through R123, while the lower plate (3) draws less current through R122. On the second half cycle, the upper (5) and lower (3) plates of V102 do the same. The voltage drop in R123 is then greater than that in R122, and the upper end of R123 becomes negative with respect to the lower end of R122. The result of a left train signal is to change the grid voltage of tube V101B in the negative direction.

The function of the first stage, then, is to change the signal from alternating current to direct current, and then to compare the signal voltage (which is an electrical indication of how far the gun is out of correspondence) with the reference voltage. The source of the reference voltage is the same as that used to generate the signal voltage. The phase difference between the two controls the polarity of the signal output to V101B. V101B is used to couple the first amplifier stage to the second. A relatively positive signal on the grid of V101B will produce a positive output signal at the cathode, while a relatively negative signal on the grid will result in a negative output. (A circuit of this kind is called a cathode follower, because the cathode voltage tends to follow the voltage changes on the grid. A cathode follower is a useful coupling circuit because it draws practically no current from the preceding stage.)

The signal output from V101B is too small, in both voltage and current, to supply the control fields of the amplidyne generator. The next step is to couple and amplify the signal voltage.

Coupling to Second Stage

The output of the first stage feeds into a series circuit of resistors R225 and R224 in the grid circuit of V101B from across R123 and R122. Between the two pairs of resistors, a resistance capacitance filter circuit consisting of R119, R120, and R121 and C104, C105 and C106 eliminates the 120 Hz ripple from the output of rectifier tubes V102 and V103. Synchronizing relay K102 and capacitor C110 (fig. 4-2) between the filter and the grid of V101B are used in the synchronizing operation described later in this chapter.

Cathode follower V101B, figure 4-3, performs the usual function of coupling first and second stages while permitting independent design of both stages. The V101B output voltage varies with the first stage output impressed on its grid, changing in a positive direction for a right train error signal and in a negative direction for a left train error signal. V101B output voltage is applied to grid 1 of the second stage paraphase amplifier V105 through R126, R146 and R147, (fig. 4-3).

Second Stage Amplification

The principal component of the second stage is paraphase amplifier V105, figure 4-3. The top half, V105A, is connected as a conventional amplifier and is controlled by the output of V101B. The output of V105A is taken from plate 2 and applied to the control grid of the third stage output amplifier tube V113 through grid resistor R166. Since a right train error signal changes the voltage of grid 1 of V105A in a positive direction, the signal increases the current flow through plate 2. This reduces the plate voltage and results in a negative change of voltage at the control grid of V113. A left train error signal has the opposite effect.

The lower half, V105B, is connected as an amplifier with a fixed grid potential determined by adjusting R141 and a variable cathode voltage. Since the two cathodes of V105 are connected in parallel, the cathode potential in V105B depends upon current flow in V105A. An increase

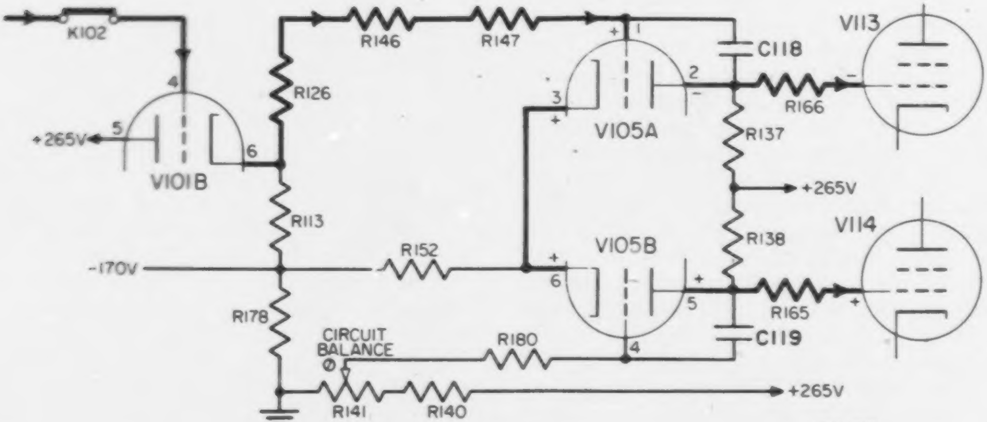


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Figure 4-3.—Second stage train amplifier, simplified schematic.

of current flow through plate 2 (right train) changes the cathode potential in a positive direction. In V105B this change has the same effect as a negative change in grid voltage and so reduces the current through plate 5. Similarly, a decrease in current in plate 2 (left train) increases current in plate 5 through grid resistor R165 to the control grid of V114. Since a right train signal decreases current in plate 5, it results in a change of voltage in the positive direction at the control grid of V114; a left train signal has the opposite effect.

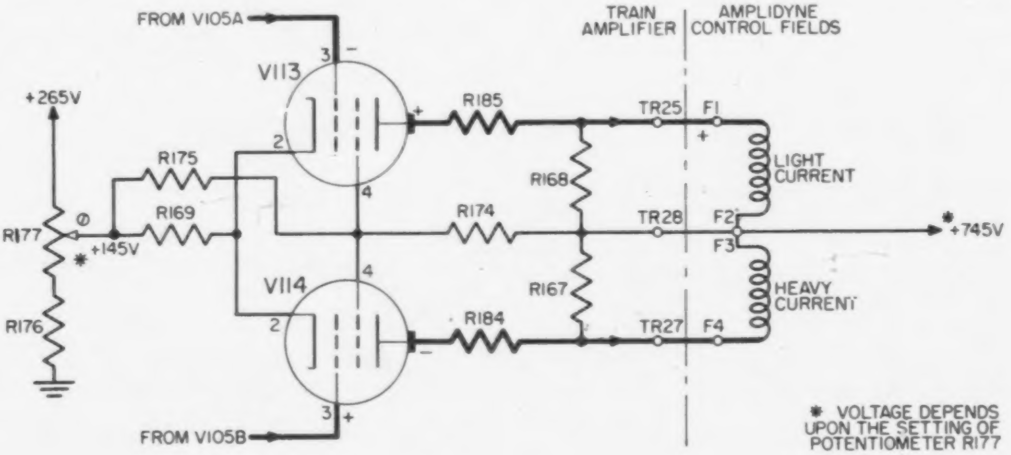
Two low-pass filter networks remove ripple voltages from grids 1 and 4 of V105. The grid 1 filter consists of R126, R146, R147, and C118. The grid 4 filter consists of R180 and C119, (fig. 4-3).

To summarize, a right train signal makes the grid of V113 more negative, and the grid of V114 more positive. A left train signal would of course have the opposite effect. And although V105 amplifies the signal voltage, it cannot supply enough current for the control windings of the amplidyne generator. Therefore the next step is to amplify the current.

Third Stage Amplification

The principal components of the third stage push-pull current amplifier shown in figure 4-4 consists of two tetrode tubes V113 and V114. These tubes are connected as conventional amplifiers; V113 supplies current to the F1-F2 control field of the amplidyne, and V114 supplies current to the F3-F4 control field. The operating level of the tubes can be adjusted by potentiometer R117 which controls the cathode potential of both tubes. As indicated in the preceding paragraphs, a right train signal changes the control grid voltage of V113 in the negative direction and that of V114 in the positive direction. It results in light current for the F1-F2 field and heavy current for the F3-F4 field. (fig. 4-4). The heavy current from the F3-F4 control field windings will cause the amplidyne generator to produce an output voltage that will train the mount to the right. A left train signal causes the control grid voltages to be reversed and thus has an opposite effect.

In the power stage (third stage), resistors R184 and R185 prevent oscillation in the output of V113 and V114. Thyrite resistors R167 and R168 provide current paths in parallel with the amplidyne control fields. These resistors have a negative temperature characteristic that reduces their resistance at high applied voltages, and also provide a certain amount of overload protection for the control fields in the event of loss of excitation voltages. Screen grid voltage for V113 and V114 is taken from a voltage divider consisting of R174 and R175.



53.58
Figure 4-4.—Power stage train amplifier, simplified schematic.

Circuit Balance

When a zero error signal is transmitted, the two sides of the motor generator (amplidyne) control field must receive equal currents. Once the operating level of V113 and V114 has been fixed by adjusting R177, the current to F1-F2 is fixed because there is a definite voltage at grid 1 of V105A that corresponds to a zero error signal. However, the current to F3-F4 for a zero signal depends upon the operating level of V105B. This level is fixed by adjusting the input to grid of V105B through the circuit balance potentiometer R141. When R141 is adjusted so that the current is equal in both halves of the control field for a zero error signal, the amplifying circuit is balanced.

Stabilizing Circuit

As the gun mount reaches a position of correspondence with the gun order signal, the drives output torque must be brought to zero. But, because of inertia, the mount tends to overtravel. This overtravel generates an error signal that reverses the direction of mount movement. Repeated overtravels result in oscillations known as hunting. To prevent hunting, three stabilizing voltages are applied to the amplifier. They are the compensating field voltage (Ic), the quadrature voltage (Iq) and the speed voltage (Is). Figure 4-5 shows the source of three voltages.

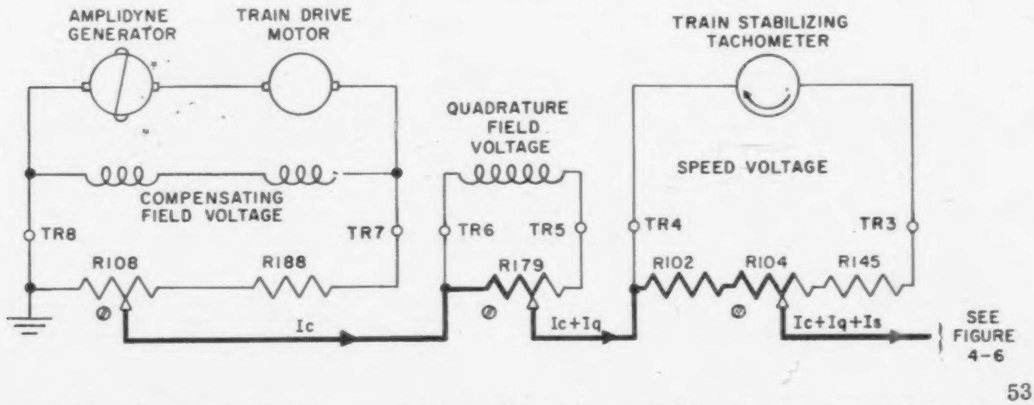
The compensating field voltage is taken from across the motor generator and drive motor compensating fields. It is proportional to the amount of current drawn by the motor from the motor generator and is used to dampen rapid, medium amplitude mount oscillations. Resistor R188 controls the percentage of compensating field voltage to be applied to the cathode follower V101A. R108 permits adjustment of the voltage. This stabilizing voltage has its greatest effect at the limit of the overswing where the drive motor is trying to reverse its direction of movement and therefore drawing a heavy current.

The quadrature field voltage is taken from across the quadrature field in the generator. It is proportional to the rate of change in the output voltage and is used to dampen high frequency, small amplitude oscillations that result in chatter and rumble in gear train assemblies. Potentiometer R179 permits adjustment of the voltage to be applied to V101A. The quadrature and compensating field voltages are combined at R179 and sent to potentiometer R104, (fig. 4-5).

The speed voltage is taken from across the rotor of the stabilizing tachometer. It is proportional to the speed of the mount and is used to prevent low frequency, large amplitude mount oscillations. The stabilizing tachometer, a small d-c generator, is driven by the train motor at speeds proportional to the speed of the mount. Resistors R102 and R145 control the portion of speed voltage to be applied to V101A; potentiometer R104 permits adjustment of the voltage. The three voltages are taken from R104 and sent to the amplifier where they are applied so as to oppose movement of the mount, (fig. 4-5).

Application

Before the stabilizing signal reaches V101A, it passes through a filter consisting of C101,



53.59

Figure 4-5.—Compensating (Ic), quadrature (Iq), and speed (Is) voltages, simplified schematic.

C102, and R105, figure 4-6. If the power drive is not hunting, the stabilizing signal is a varying d-c. Thus, the capacitors in the filter block the flow of current and grid 1 of V101A is unaffected. If the power drive is hunting, the polarity of the stabilizing signal changes with each oscillation of the mount. Thus, the stabilizing signal becomes a true a-c voltage with the same frequency as the hunting frequency and is passed by the filter to grid 1 of V101A.

In normal operation, the gun must swing back and forth with the pitch and roll frequency but in an opposite direction to the roll and pitch of the ship. Because this frequency is less than hunting frequencies, the capacitors and resistors are chosen to form a highpass filter network that will pass current at hunting frequencies but will block current at the low frequencies resulting from system operation compensation for ship movement.

If the gun has passed the correspondence point and is hunting, the stabilizing voltage will be a-c with a frequency high enough to pass through the filter capacitors C101 and C102. A right train overshoot changes the grid voltage of V101A to negative, provided it is of short enough duration to pass the filter network. Resistor R115 (fig. 4-6), connected to the grid of tube V101A, acts as a load resistor for the filter network and a voltage bias resistor for the grid. As grid 1 of V101A changes negatively, less current flows to the cathode bias resistor R112. This resistor is also part of the V101B grid 4 circuit. The change in current flow through R112 causes V101B grid 4 potential to move in a negative direction reducing the positive effect of the right train signal applied to the same grid circuit by the output of tubes V102 and V103 (fig. 4-2). Since the effect of the stabilizing voltage is to reduce the effect of the error signal as the mount approaches correspondence, it reduces the speed of travel and thereby shortens the next overswing. When the gun passes the correspondence point and starts to swing back under the influence of the left train signal, the stabilizing voltage is reversed and its effect opposes that of the left train signal. Thus, an opposing force is applied to the load in either direction in train, with the result that hunting is effectively stopped.

The operation of the amplifier is the same regardless of whether the order signal comes from a director or a local control station. The circuits and devices used to produce or modify gun order signals are the next subject to be discussed.

AUTOMATIC CONTROL CIRCUITS

In automatic control, synchros are used to compute and transmit gun error and gun order. To ensure both accuracy and speed, ordnance synchro systems are usually subdivided into a coarse (1-speed) and a fine (36-speed) circuit. The details of operation and maintenance of

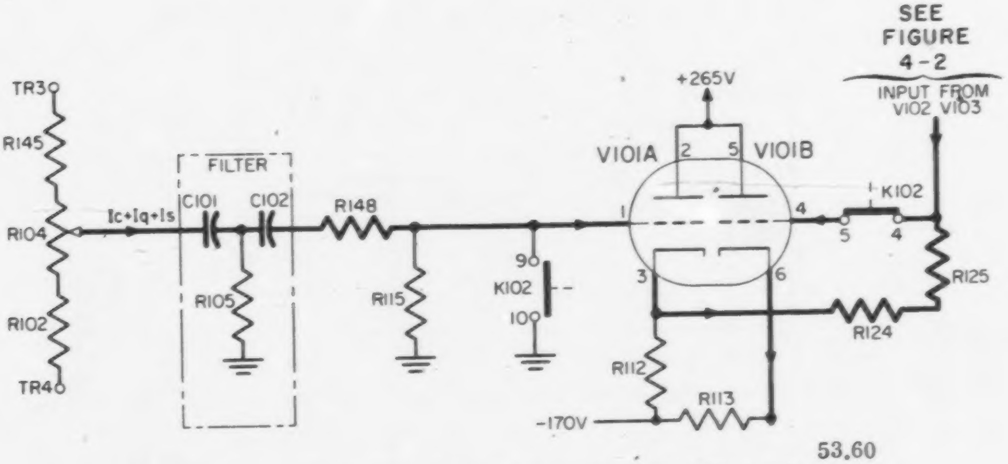


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Figure 4-6.—Stabilization output circuits, simplified schematic.

synchros and synchro circuits are spelled out in earlier chapters of this text. The synchro system used in the Mk 35 power drive is typical of those you are familiar with.

When the mount is more than about 2° out of correspondence, the amplifier receives the 1-speed error signal, but not the 36-speed signal. A synchronizing relay is used to select the signal to be applied to the amplifier.

Synchronizing Relay K102

Figure 4-7 shows the synchronizing relay, K102, and the circuit that controls its action and thus determines whether the fine or coarse signal will be sent to the amplifier. When the relay is energized, the mount is in coarse control, and the 1-speed error signal is transmitted through contacts 11 and 12. When the relay is deenergized, contacts 7 and 8 are closed, connecting the fine signal to the amplifier. This is the condition shown in figure 4-7.

In fine control, V110B is conducting heavily and V109 only slightly—not enough to actuate the synchronizing relay.

When the gun gets more than about 2° out of synchronization, a 1-speed signal is applied to transformer T103 from terminals TR11 and TR12 of the train amplifier. The secondary of T103 is connected to the grid and cathode of V110B. The positive swing of an incoming coarse a-c signal will have little effect on the tube, because it is already passing nearly its maximum current. During each negative swing of the input signal, tube current will decrease. And, as the average tube current decreases, the average plate potential rises.

Tube V109, which has been conducting only slightly, now receives the positive signal from V110B on its grid. This increases the current flow through the tube, and through the synchronizing relay in its plate circuit. When the coarse signal is of sufficient magnitude, K102 will operate.

When relay K102 is energized by the coarse control signal, as in figure 4-8, the mount is at least 2° from correspondence. In this condition the three stabilization voltages are not required, and contacts 9 and 10 of K102 will short them to ground. In their place, a voltage proportional to the current drawn by the drive motor and generator is used. It is drawn from the adjustable potentiometer, R144, and its output goes through V104 to the grid of V105A. V105, you remember, controls the two tubes in the third (power) stage of the amplifier.

In fine control, the signal voltage is taken from the top of R125, across contacts 4 and 5 of the synchronizing relay, and applied to the grid of V101. In coarse control, K102 opens contacts

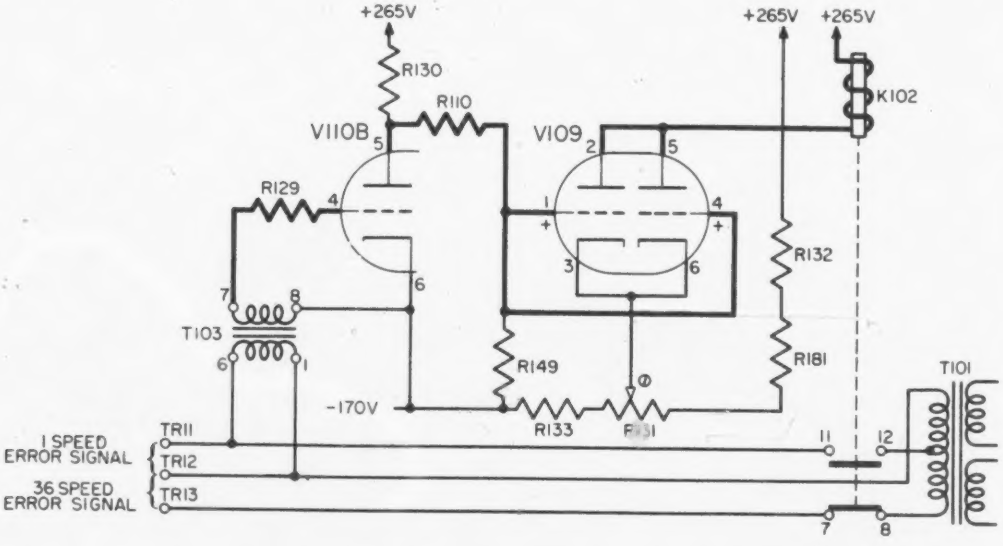

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Figure 4-7.—Energizing synchronizing relay, simplified schematic.

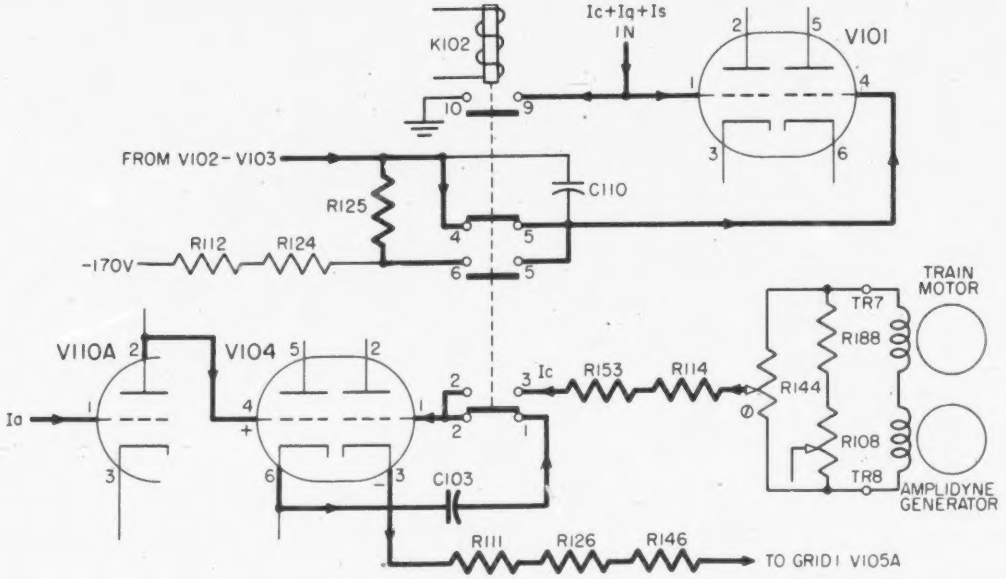

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Figure 4-8.—Effect of relay K102 on stabilization, simplified schematic.

4 and 5, while closing 5 and 6. This causes the signal to be taken from a point on the voltage divider formed by R125, R124, and R112, rather than directly from the input.

Abrupt changes in input voltage are transmitted to V101 directly through C110, rather than just through the voltage divider. This makes the system more responsive, and helps to prevent overtravel. Compare figure 4-8 with figure 4-2, to see how the stabilization circuit is related to the first stage amplifier circuit.

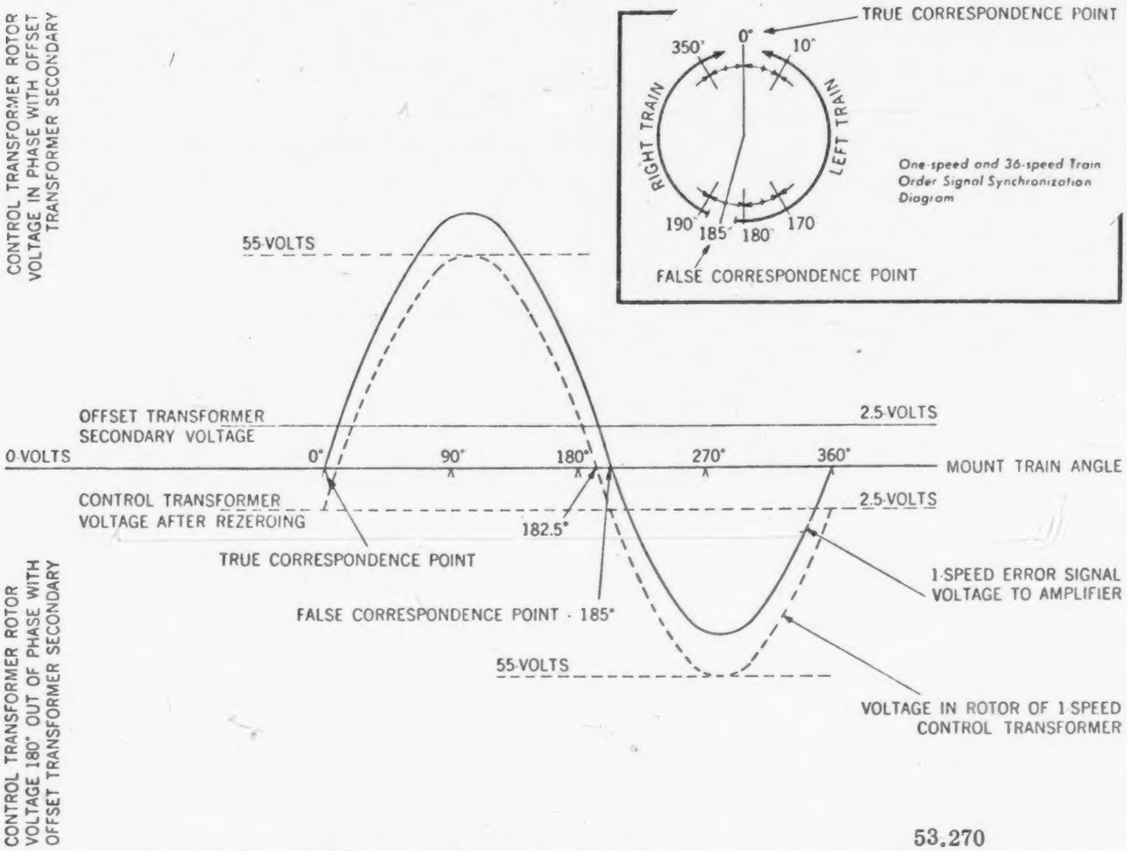
Offset Transformer

The 1-speed error signal, however, cannot be used directly, since it has a false correspondence point 180° from the true correspondence. At this point, the synchro rotor is at right angles to the magnetic field and the induced error signal voltage is zero, just as it is at true correspondence. For a small distance each side of the false correspondence point, there is a dead space in which the 1-speed error signal is too weak to actuate the synchronizing relay. If the control-selector switch were shifted to AUTO with the mount in this dead space, the 36-speed signal would run it to the false correspondence point and hold it there.

To avoid this difficulty, the error signal is modified and the 1-speed train control transformer is zeroed in such a manner that the false correspondence is shifted about five degrees. With the false correspondence point 185 degrees from the true correspondence, the 36-speed signal runs the system out of the dead space instead of centering it there (fig. 4-9).

The 36-speed error signal also has a false correspondence point (five degrees from true correspondence), but this signal has no dead space—so the slightest movement of the signal or the mount will throw it off balance and start it in one direction or the other.

The 1-speed error signal is modified by adding to it a voltage from the secondary winding of an offset transformer. As shown in figure 4-10, the secondary winding of the offset transformer is inserted in series with the R2 lead of the train 1-speed synchro control transformer. The polarity signs of figure 4-10 indicate that 2 1/2-volt a-c potential in the transformer secondary winding is equivalent to a signal called for about 2 1/2 degrees of right train. Consequently, in order that the error-signal voltage at train amplifier terminals TR11 and TR12 may drop to zero when the mount is in correspondence with the 1-speed train order signal,


TRUE CORRESPONDENCE POINT
350°
0°
10°
RIGHT TRAIN
LEFT TRAIN
One-speed and 36-speed Train Order Signal Synchronization Diagram
190°
185°
180°
170
FALSE CORRESPONDENCE POINT
CONTROL TRANSFORMER ROTOR VOLTAGE IN PHASE WITH OFFSET TRANSFORMER SECONDARY
55-VOLTS
OFFSET TRANSFORMER SECONDARY VOLTAGE
2.5-VOLTS
0-VOLTS
0°
90°
180°
270°
360°
MOUNT TRAIN ANGLE
CONTROL TRANSFORMER VOLTAGE AFTER REZEROING
2.5-VOLTS
182.5°
TRUE CORRESPONDENCE POINT
1-SPEED ERROR SIGNAL VOLTAGE TO AMPLIFIER
FALSE CORRESPONDENCE POINT - 185°
55-VOLTS
VOLTAGE IN ROTOR OF 1-SPEED CONTROL TRANSFORMER
CONTROL TRANSFORMER ROTOR VOLTAGE 180° OUT OF PHASE WITH OFFSET TRANSFORMER SECONDARY

53.270

Figure 4-9.—Modification of one-speed train order signal, phase diagram.

the stator of the 1-speed train control transformer (CT) must be shifted 2 1/2 degrees in such a direction that an error signal voltage is induced in the rotor windings calling for 2 1/2 degrees of left train. By rezeroing the 1-speed control transformer, the false correspondence point is shifted about five degrees, because the addition of the offset transformer voltage moved the false correspondence point 2 1/2 degrees, and the rezeroing of the 1-speed control transformer shifted it another 2 1/2 degrees in the same direction, making a total shift of five degrees.

If the mount is shifted to automatic and is 180° from true synchronization, the modified error signal causes a phase difference between the signal and reference voltages in the first stage of the amplifier. This phase difference causes the mount to train in the correct direction for true synchronization.

To sum up the action of the offset transformer, it can be stated that it effectively establishes a single zero position for the rotor of the 1-speed control transformer, eliminating the possibility of 180° error in the system.

LOCAL CONTROL CIRCUITS

In LOCAL control, the error signal to the amplifier originates at a one-man control (OMC) station on the mount. There are two such stations for this power drive. Either, but not both at once, can deliver gun error signals for train

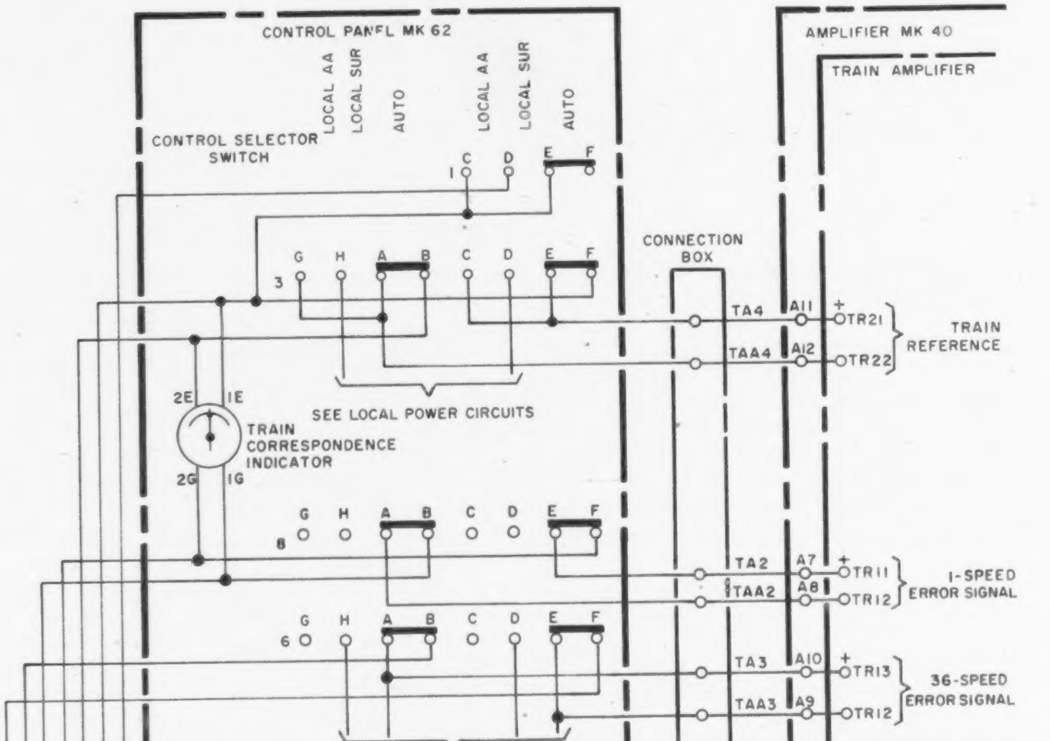
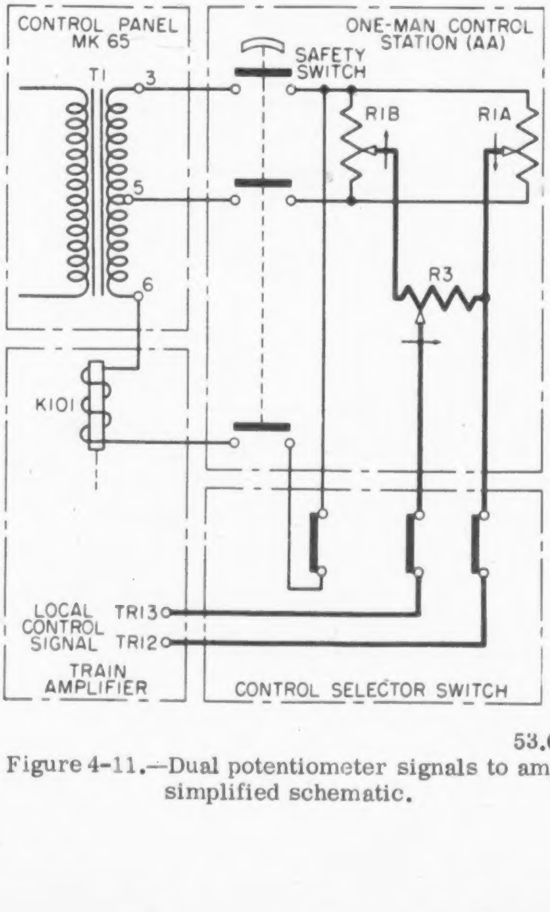

CONTROL PANEL MK 62
LOCAL AA
LOCAL SUR
AUTO
LOCAL AA
LOCAL SUR
AUTO
CONTROL SELECTOR SWITCH
1 C D E F
3 G H A B C D E F
CONNECTION BOX
AMPLIFIER MK 40
TRAIN AMPLIFIER
TA4
TAA4
A11
A12
+
TR21
TR22
TRAIN REFERENCE
SEE LOCAL POWER CIRCUITS
2E
1E
TRAIN CORRESPONDENCE INDICATOR
2G
1G
8 G H A B C D E F
TA2
TAA2
A7
A8
TR11
TR12
1-SPEED ERROR SIGNAL
6 G H A B C D E F
TA3
TAA3
A10
A9
TR13
TR12
36-SPEED ERROR SIGNAL
SEE LOCAL POWER CIRCUITS
CONTROL PANEL MK 65 (OR MK 108)
CR2
TO BRAKE RELEASE CIRCUIT AND PLATES OF POWER SUPPLY UNIT FOR AMPLIDYNE FIELDS.
CONNECTION BOX
SC24
21
20
19
2GM1
TRAIN SYNCHRO SUPPLY
2GMM1
TRAIN ORDER SIGNALS FROM COMPUTER
TD1
TDD1
TD2
TDD2
W8
W9
TRAIN RECEIVER REGULATOR
TB1-1
TB1-2
CC1
RR1
RR2
RR3B
RR3A
OFFSET TRANSFORMER
TB1-4
TB1-3
X6
X5
X3
X4
R2
R1
1CT 1-S
S1
S2
S3
L
Z1
Z2
Z3
2GM11
2GM12
2GM13
1-S
R1
R2
5MCT 36-S
S3
S2
S1
J
Z4
Z5
Z6
2GM14
2GM15
2GM16
36-S

Figure 4-10.—Signal circuits to amplifier, train system, AUTO control. 53.211

and elevation. Figure 4-11 shows the LOCAL AA station train circuits. Initially, when the safety switch (deadman's switch) is closed, two things happen. A voltage is placed across the two potentiometers R1A and R1B, and the local control relay in the train amplifier is energized.

Local Control Signal

R1A and R1B are a balanced bridge circuit. They furnish the error signal for local control. When the OMC housing is centered, the movable fingers of the potentiometers are also centered, and there is no potential difference between them. When the OMC housing is deflected, the fingers will move in opposite directions along the potentiometer windings. This will cause a potential difference between them and current will flow through R3. The signal to the amplifier is picked off the adjustable potentiometer, R3. The amount of OMC deflection will determine the magnitude of the signal, and the direction of deflection will determine its phase.



53.63
Figure 4-11.—Dual potentiometer signals to amp, simplified schematic.

Aided Tracking Tachometer

In addition to the potentiometer signal, a d-c voltage is supplied by a tachometer generator in the OMC (fig. 4-12). The voltage introduced by the aided tracking tachometer aids the potentiometer signal in overcoming mount starting inertia. The tachometer voltage is taken off potentiometer R2, and applied to the amplifier as shown in figure 4-12.

When K101 is energized, one set of contacts shorts the grid of V110B to its cathode. This keeps K102 from operating and therefore, keeps the synchronizing circuits disconnected. Another set of contacts of relay K101 connects the aided tracking tachometer to the grid of V101A. Still another set of contacts connects the three stabilizing voltages to the aided tracking voltages.

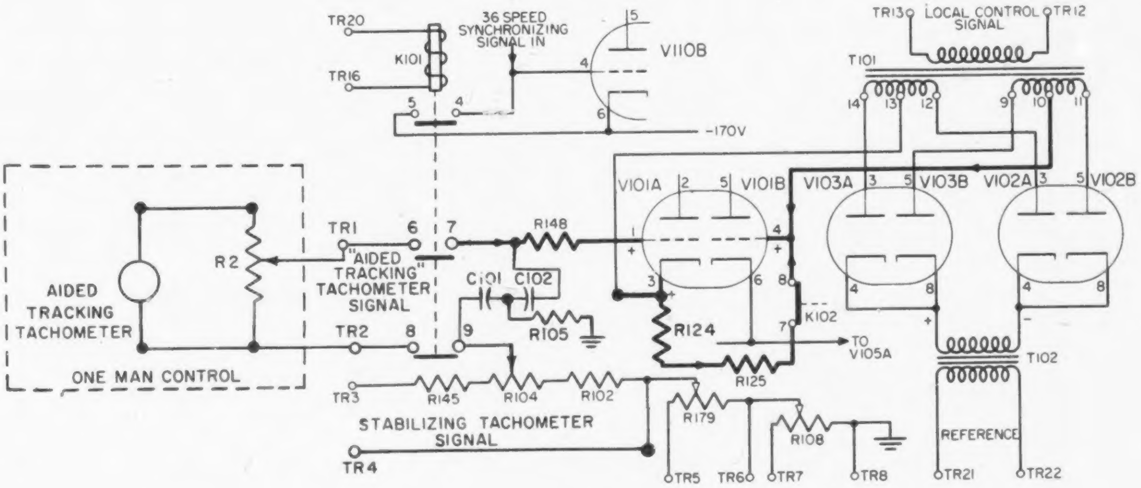
When the mount is stationary, there is no voltage input to the grid of V101A. If the OMC is deflected in such a direction as to call for right train, the tachometer will generate a positive signal which is coupled to the grid of V101A. The resultant positive voltage change is taken off the cathode of V101A and transmitted to the grid of V101B. As you may remember, a positive signal on the grid of V101B has the effect of a right train signal.

The aided tracking tachometer supplies a signal only while the OMC housing is moving. When the OMC stops (except in its neutral position), the local control signal from the dual potentiometers keeps the mount moving. The local control signal is now applied to the transformer T101 in the amplifier, where it has the same effect as an automatic signal on the principal amplifier circuits.

Stabilizing Voltages

Once the mount starts to move, the stabilizing voltages are applied directly to the grid of V101A, where they oppose the signal voltage. The dominating stabilizing voltage comes from the stabilizing tachometer. The output of this tachometer is proportional to mount speed.

For a right train signal, the negative output of the stabilizing tachometer increases as the mount speed increases, until it balances the effect of the local control signal. Then no further increase in mount speed is possible, unless the OMC is moved farther off center to increase


TR20
TR16
K101
36 SPEED SYNCHRONIZING SIGNAL IN
V110B
-170V
TR13
LOCAL CONTROL SIGNAL
TR12
T101
V101A
V101B
V103A
V103B
V102A
V102B
AIDED TRACKING TACHOMETER
R2
ONE MAN CONTROL
TR1
"AIDED TRACKING" TACHOMETER SIGNAL
TR2
R148
C101
C102
R105
R124
K102
R125
TO V105A
T102
TR3
R145
R104
R102
STABILIZING TACHOMETER SIGNAL
TR4
R179
R108
REFERENCE
TR5
TR6
TR7
TR8
TR21
TR22

53.64

Figure 4-12.—Local control circuits, simplified schematic.

the signal voltage. If the OMC is moved back toward its center position, the stabilizing tachometer voltage will exceed the signal voltage. This is equivalent to a left train signal, and will slow the mount down until a balance is reached. In local control, then, the stabilizing tachometer acts as a governor to control mount speed.

POSITION, SPEED, AND CURRENT-LIMITING CIRCUITS

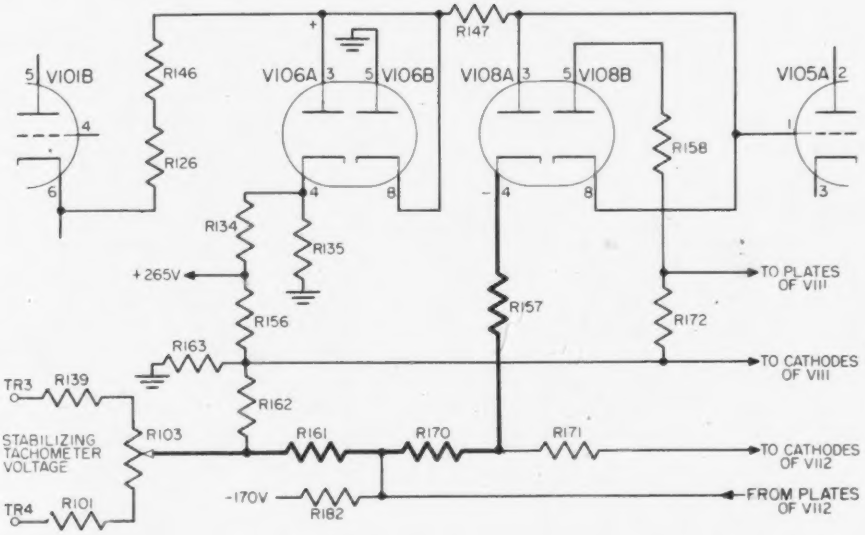
The amplifier circuits are capable of generating gun train and elevation signals which, if they were not limited, could damage the power drive components. The signal limiter tube, V106, is shown in figure 4-13. It keeps excessive train signals from reaching V105A.

Plate 3 of V106A and cathode 8 of V106B are connected between R146 and R147 on the line leading to grid 1 of V105A. When there is no train signal from V101B, this point is positive with respect to ground. Cathode 4 of V106A is connected to a point on voltage divider R134 and R135; this point is more positive than plate 3 of V106A. When the right train signal exceeds a certain amplitude, plate 3 will become positive with respect to cathode 4; V106A will then conduct, and thus limit the right train signal. The other half of the limiter tube, V106B, will act in a similar manner to provide limiting action on the negative left train signals.

The operational speed of the mount is limited by a voltage, proportional to speed, taken from the stabilizing tachometer. This voltage is applied to the amplifier at terminals TR3 and TR4, and reduces the effect of the gun train signals.

Cathode 4 of V108A is tied, via R157 and R170, to a point of negative potential on the resistor network made up of R156, R163, R162, R161, and R182. The output of V112 is a pulsating direct current, drawing current through R170 and causing a voltage drop across it, thus raising cathode 4 of V108A to a relatively high positive potential. When there is no train signal, plate 3 of V108A is less positive than cathode 4, and V108 will not conduct.

When the mount trains to the right, the stabilizing tachometer introduces a negative voltage at a point between R161 and R162. As a result, all points on the voltage divider will shift in a negative direction. The negative shift becomes greater as the mount speed increases. If the right train signal calls for a speed greater than the desired limiting speed, this shift in potential will be sufficient to make cathode 4 of V108A negative with respect to the plate, and this half of the tube will conduct. When V108A conducts, it draws current from the line that carries the right train signal. This decreases the signal at grid 1 of V105A; the mount does not follow at the speed called for,



53.65

Figure 4-13.—Speed limit circuits, simplified schematic.

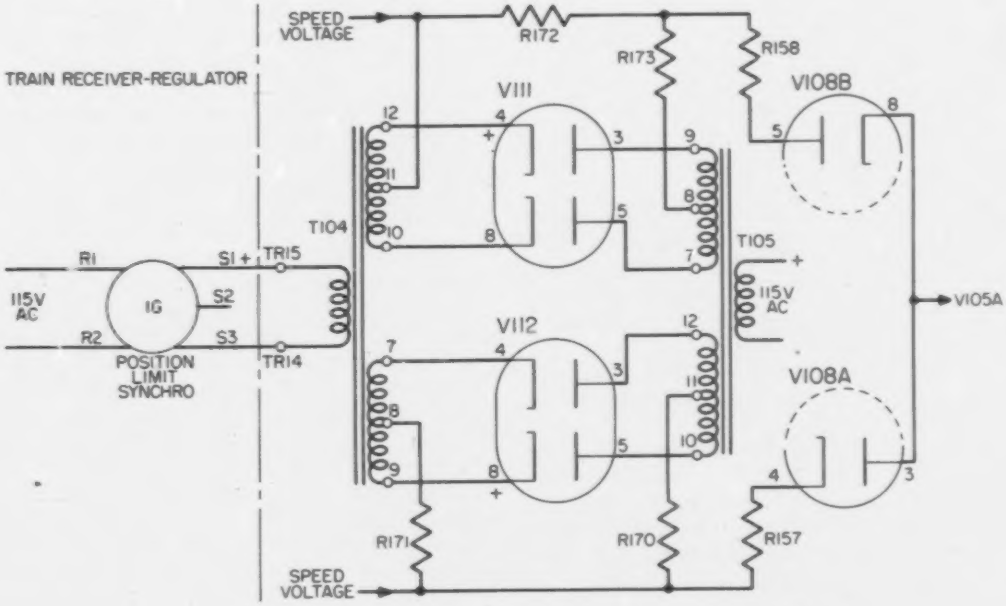
and lags behind the gun director (in automatic) or the one-man control (in local). V108B, in conjunction with V111, acts in a similar manner to limit the negative left train signal on the grid of V105A. As the mount lags behind, because its speed is limited by V108, the train signal tends to increase. But the signal on the grid of V105A does not increase, because of the limiting action of V106. The position of the mount is also electrically limited to keep the power drive from slamming it against the mechanical limit stops. As the mount approaches one of the stops, moves the rotor of a synchro generator in the limit stop mechanism. This synchro generator produces a limit signal that gets stronger as the mount approaches the mechanical stops.

Now, let's assume that the mount is approaching the mechanical limit while training to the right. A signal from the limit synchro generator appears across the primary of T104 (fig. 4-14). On one particular half cycle of the plate reference voltage at T105, plate 5 of V112 will be positive and this section of the tube will conduct. The rotor of the limit signal generator is excited by the same 115 a-c source as the primary of T105. Consequently, for this particular half cycle, the limit signal on cathode 8 of V112 will be positive. This reduces the conduction of the lower section of V112, and so reduces the current through R170. This, in turn, makes cathode 4 of V108A more negative.

If the mount is training at maximum speed as it approaches the limit, the combined effect of the speed signal and the limit signal is strong enough to cause an immediate reduction in speed. As the speed drops, the strength of the speed signal decreases and that of the limit signal increases until a point is reached at which the limit signal exceeds the right train signal. The resultant signal on grid 1 of V105A has the effect of an electrical brake, and the mount stops. Since the limit signal depends only on mount position, the mount will always stop at the same point, no matter how fast or how slow it approaches the limit.

As the mount approaches its left limit, the signal from the limit synchro reduces the current drawn by the rectifier tube V111. V111 then acts to bring the mount to a stop at the left limit, as V112 does at the right limit.

The CURRENT drawn by the train motor must be limited to prevent sudden changes in motor speed which would be dangerous to personnel and equipment. To do this, the error signal on grid 1 of V105A is modified by V107. The operation of V107 is similar to that of the speed and position limiter, V108.


SPEED VOLTAGE
R172
R173
R158
TRAIN RECEIVER-REGULATOR
V111
V108B
12
4
+
3
9
5
11
8
T104
10
8
5
7
T105
R1
S1 +
TR15
+
115V AC
1G
S2
115V AC
V105A
R2
S3
POSITION LIMIT SYNCHRO
TR14
V112
12
7
4
3
V108A
11
8
5
10
9
8
+
4
3
R171
R170
R157
SPEED VOLTAGE

53.66

Figure 4-14.—Position limit circuits, simplified schematic.

SUMMARY OF THE AMPLIFIER ACTION BY TUBES

TUBE	ACTION
V101A	Input—automatic control, stabilizing voltage; local control, aided tracking and stabilizing voltage. Output—from cathode, to grid of V101B; modifies signal on grid.
V101B	Input — rectified error signal from V102 and V103. Output—from cathode, to V105.
V102 and V103	Input—error signal and reference voltage. Output — rectified error signal to V101B.
V105A	Input—error signal from V101B. Output—error signal to grid of V113.
V105B	Input — voltage drop in cathode resistor, caused by signal to V105A. Output—to grid of V114.
V105	This stage is called a phase inverter; it preceeds a push-pull stage. Signals to push-pull must be equal and opposite.
V106	Input—potential difference between signal to grid of V105 and a predetermined potential. Output — limits signal strength of amplifier by shunting action.

V107	Input—potential difference between signal to grid of V105A and quadrature voltage level. Output — limits current changes in amplidyne generator by shunting action.
V108	Input—potential difference between signal to grid of V105A and a predetermined level, plus the stabilizing tachometer voltage. Output—limits speed of mount by shunting action.
V109	Input—voltage swing proportional to coarse error signal from V110B. Output—current to operate synchronizing relay K102.
V110	Input—coarse error signal. Output — voltage swing, proportional to coarse error signal, to V109.
V111 and V112	Input—position limit synchro signal, reference voltage, and stabilizing tachometer voltage. Output—limits position of mount movement in power by limiting grid signal to V105A by shunting action of V108.
V113 and V114	Input—error signals from V105. Output—amplified power signal to control fields of amplidyne generator. This is a push-pull stage.

MOTOR FIELD CONTROL CIRCUITS

These circuits supply the excitation voltages for the drive motor fields. The current flow through the field windings must remain constant. A small change would result in a relatively large change in motor speed.

The maximum speed of the elevation drive motor is 1500 rpm, with a corresponding elevation rate of 24 degrees per second. This speed is obtained with a field excitation of 1.4 amps. Speeds in excess of 1500 rpm are obtained by the train drive motor by a reduction of field excitation. This reduction of field excitation reduces the cemf generated by the motor, and thus increases motor speed. The maximum train rate is 30 degrees per second.

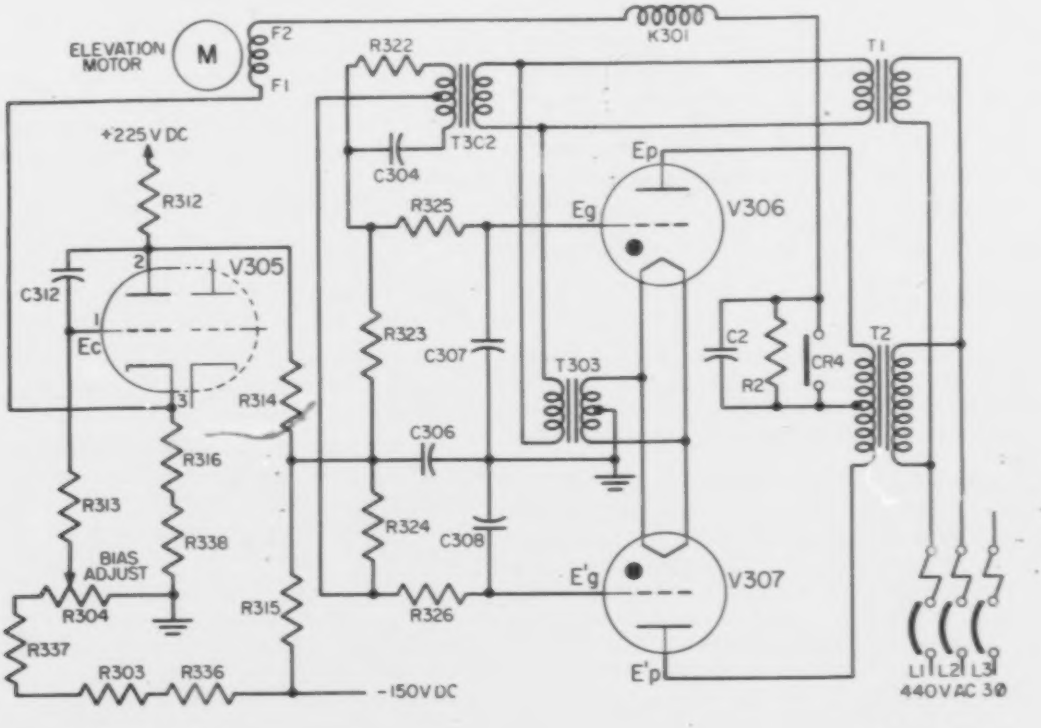
Figure 4-15 shows the elevation motor field control circuit. (The circuit for the train motor is similar, except for its higher speed.) Tubes V306 and V307 are connected to the secondary of transformer T2 so as to give full-wave rectification. The dot in the tubes indicates that they are gas filled. A gas-filled triode is called a thyratron. The grid-voltage determines the plate voltage at which the thyraton will fire, and begin to conduct. Once the tube starts to conduct, the gas ionizes and becomes effectively a short circuit through the tube. The grid then loses control of the tube until the gas de-ionizes. With alternating current on the plate, this will happen during alternate half cycles.

The grid bias of V306 and V307 is controlled by V305. The current in the motor field, F1-F2, flows through cathode resistors R316 and R338, and thus affects the bias of V305. An increase in current flow will cause the cathode to swing in a negative direction, resulting in more current flow through V305. This reduces the plate potential. The plate potential is coupled to the grid of V305 through R314, R323, and R325; and to the grid of V307 through R314, R324, and R326. Thus these grids are controlled, indirectly, by the current flow through the field of the drive motor. In effect what we are doing is taking continuous measurements of the field current, and applying any change to the source of the current, V306 and V307, to cancel the change.

Winding K301 is the coil of relay K301, which deenergizes the power supply unit and applies the brake if we lose the drive motor field excitation.

MAINTENANCE

Maintenance procedures are of two kinds: (1) preventive (or routine), and (2) corrective (repair of casualties, etc.). You will find guides to electrical maintenance procedures in chapter 2 of this text. Amplidyne power drives, being


ELEVATION MOTOR
M
F2
F1
K301
T1
R322
T3C2
C304
+225 V DC
R312
R325
Ep
Eg
V306
C312
2
V305
1
Ec
3
R314
R323
C307
T303
C2
R2
CR4
T2
C306
R316
R313
R338
R324
C308
E'g
V307
BIAS ADJUST
R304
R315
R326
R337
R303
R336
-150V DC
E'p
L1
L2
L3
440V AC 3Ø

53.67

Figure 4-15.—Elevation motor field control circuits, simplified schematic.

electrical machines, can be maintained by following these guidelines.

PREVENTIVE MAINTENANCE

A preventive maintenance program should be prepared for all components of the power drive. A procedure, and a timetable for its accomplishment, should be established. One essential item of preventive maintenance is the transmission check. Frequent transmission checks help to uncover malfunctions as they occur, and make corrective maintenance comparatively easy. If neglected, malfunctions accumulate, and their correction becomes more difficult and time consuming. The steps of the maintenance procedure are given in the OP for each equipment. These OPs are especially helpful in making adjustments.

ADJUSTMENTS

Adjustments are made to compensate for variations in circuit component values, and for variations from standard or designed conditions.

Generally, adjustments are required when, over long periods, the equipment performance characteristics become less than optimum. Sudden changes in equipment performance characteristics are interpreted as component failures. If it becomes necessary to replace a component, a critical analysis of the associated circuit must be made to determine if compensating adjustments should be made.

So, "when to make adjustments" becomes a matter of common sense and judgment. Making unnecessary adjustments will result in wasted time and effort. Trying to compensate for equipment casualties by making adjustments will result in substandard performance, and may cause additional circuit casualties.

CORRECTIVE MAINTENANCE

Corrective maintenance is required when a component breaks down (a malfunction). Electrical casualty analysis, like the analysis of casualties in any complex machine, must be based on a full understanding of the principles and characteristics of the equipment's operation. In these two chapters on amplidyne power drives, we have tried to give you such an understanding.

When casualties occur in your equipment, you will need a logical, step-by-step procedure of casualty analysis to uncover them. This procedure is basically one of eliminating areas where the fault does not lie, starting with large areas and gradually narrowing down to smaller and smaller segments until the fault reveals itself.

Sample Casualty

Casualty analysis will play a very important part in your maintenance program. For a better understanding of the procedures, follow along as we go through a sample problem, from beginning to end.

Suppose that, during a transmission check one day, you discover that one of your twin 3"/50 mounts moves sluggishly in train. Furthermore, the sluggishness is more apparent with a left train signal than with a right train signal. Also, let's assume that this condition is observed while the gun is in automatic control. It is obvious that one or more of the following units is not operating properly.

1. The synchros that originate the error signals
2. The train amplifier
3. The train amplidyne

But these three possibilities cover a large area. Let's start our elimination process with the synchros, by switching the selector switch to a LOCAL station. Synchro signals, you know, are not used in LOCAL control. Upon switching to LOCAL, however, you find that you still have the original trouble. That eliminates the synchros as a possible source of trouble.

The next item on our list of possibilities is the train amplifier. As you remember, the last stage (power stage) of the amplifier is connected to the control fields of the amplidyne generators. We can check the output of the amplifier, then, by measuring the voltage drop across amplidyne fields F1-F2 and F4-F3. We measure the voltage drop across the F4-F3 field with a 5-degree right train signal, and the voltage drop across the F1-F2 field with a 5-degree left train signal. This check reveals that the voltage drop across the F1-F2 field is much smaller than across the F4-F3 field. Now we have established that the casualty is somewhere in the train amplifier.

A look at the circuits in the train amplifier shows us that the trouble must be in the circuits associated with V106, V107, V108, V111, or V112 since these circuits control the right or left train signal limiting. (If the trouble had been in any of the other circuits, we would have found identical symptoms on both right and left train signals.)

Now we must examine each of the possible casualties.

If V106, V107, or V108 were inoperative, there would be no signal limiting, and consequently mount train would not be sluggish.

If either half of V106, V107, or V108 were shorted, the mount would be sluggish on both right and left train signals.

If V112 were inoperative, cathode 3 of V108A would become negative because of the loss of circulating current through R170. This would limit RIGHT train signals more than left train signals.

If V111 were inoperative, plate 5 of V108B would become positive because of the loss of circulating current through R172. This would limit left train signals more than right train signals and COULD cause our trouble.

The thing to do now is to check the voltage at plate 5 of V108B. In measuring the voltage at plate 5 we find it to be positive. This definitely determines that V111 is not operating properly. All that is left to do is to check the tube and replace it with a new one.

Before we secure, however, we should check balance adjustment R141, and speed adjustment R103, to see if readjustment is necessary.

SAFETY

The primary reason for the vast amount of information available on the subject of safety precautions is simply the desire to prevent accidents. Research has shown that at least 75% of all accidents occur through sheer carelessness. Not only is there a loss of time involved in an accident, but also there is an accompanying loss of either equipment, material, or, in the extreme case, life itself.

As a leading Gunner's Mate, your responsibilities regarding electrical safety may be grouped into two basic areas.

1. Responsibilities concerning the GM group or weapons system. These responsibilities include

ensuring that all men in gun gangs are aware of and are observing all shipboard safety precautions especially those regarding electrical and electronic safety.

2. As a GM1 or Chief Gunner's Mate, you will automatically be considered an expert in your rate and also an expert in all types of safety precautions. Thus you have a responsibility to properly educate the men under your supervision in all types of electrical and electronics safety related to ordnance equipment. The responsibilities in this area are ever increasing as more complex electrical and electronic equipments are being utilized for ordnance equipment.

Since weapon systems utilize many different types of equipment and components, it would be unwise to try to develope safety rules in great depth for each of these types. Since almost all types of ordnance equipment use electricity for some purpose, we will discuss what electric shock can do to the human body.

ELECTRIC SHOCK

Current flow through the body is the cause of electric shock. Factors determining the extent of the body damage due to electric shock are the amount and duration of the current flow, the parts of the body involved, and the frequency of the current if a-c. In general, the greater the current or the longer the current flows, the greater will be the body damage. Body damage is also greatest when the current flow is through or near nerve centers and vital organs. Sixty Hertz current is considered slightly more dangerous than current of a lower frequency or d-c. This difference is small, however, and the same precautions that apply to 60-cycle a-c also apply to d-c.

Men differ in their resistance to electric shock, and consequently a current flow that may cause only a painful shock to one man might be fatal to another. Table 4-1 presents information from authoritative sources on the effects of 60 Hertz currents flowing through the body from hand to hand or hand to foot. NAVSHIPS Technical Manual summarizes the effects of 60 Hertz currents with 3 brief statements as follows:

1. At about 1 ma (.001 ampere), shock is perceptible.

2. At about 10 ma (.010 ampere), shock is sufficient to prevent voluntary control of the muscles.

3. At about 100 ma (.1 ampere), shock is fatal if it lasts for 1 second or more.

Table 4-1.—60 Hertz current values affecting human beings.

Current Value	Effects
Less than 1 ma	No sensation.
1 to 20 ma	Mild sensation to painful shock, may lose control of adjacent muscles between 10 and 20 ma.
20 to 50 ma	Painful shock, severe muscular contractions, breathing difficult.
50 to 200 ma	Same as above, only more severe, up to 100 ma. A heart condition known as ventricular fibrillation may occur anywhere between 100 and 200 ma causing death almost immediately.
Over 200 ma	Severe burns and muscular contractions so severe that the chest muscles clamp the heart and stop it for the duration of the shock.

67.111

High frequency currents ranging from about 200Hz and above have a tendency to flow along the surface of the skin (skin effect) and persons coming into contact with these currents usually suffer severe burns although the current may not penetrate the body. In addition to the possibility of severe burns or death, involuntary movements as a result of electrical shock can cause other types of serious injuries resulting from falls, contact with rotating machinery or heated materials, etc.

Serious injuries of this nature can occur without the real cause receiving widespread attention. Two conditions must be present for an electric current to flow through the body and cause electric shock.

1. The body or some part of the body must form part of a closed circuit.

2. Somewhere in the closed circuit there must be a voltage or a difference in potential, to cause a current flow. It follows then, to prevent electric shock you should, if possible, ensure that your body never forms part of a closed circuit.

Tests made by the National Bureau of Standards show that the resistence of the human body may be as low as 300 ohms under unfavorable conditions such as those caused by salt water and perspiration. This indicates immediately that it is possible for a potential difference as low as 30 volts to cause the fatal .1 ampere current flow through the body. It is true that this could be an extremely unfavorable condition; however, it leaves no doubt as to the dangers involved and precautions necessary regarding the 120-volt circuits aboard ship.

Practically all electric shocks are due to human failure, rather than equipment failure. Equipment may suddenly fail and cause fatal shock even if skillfully designed for safety, thoroughly tested before use, and used in accordance with applicable safety precautions. This can happen, but rarely does. Nearly all the shipboard deaths are caused by human failure manifested in one or more of the following ways:

1. Unauthorized use of, or unauthorized modifications to, equipment.
2. Failure to observe the applicable safety precautions when using equipment or when working on or near energized equipment.
3. Failure to repair equipment which was known to be defective and had previously given a mild shock to users.
4. Failure to test and inspect equipment for defects or failure to remedy all defects found by tests and inspections. All of these failures may be summarized as failure to observe applicable safety precautions.

Records show that seven out of ten victims of electric shock were revived when artificial respiration was started in less than 3 minutes after the shock. After 3 minutes the chances of revival decrease rapidly.

All shipboard personnel should be made aware of the fact that a victim rendered unconscious by electric shock should receive artificial respiration, and that it should be started in a matter of seconds rather than minutes. To this end the person nearest the victim should start the resuscitation without delay and call or send others for assistance and medical aid. The only logical permissible delay is that required to free the man from his contact with the electricity in the quickest, safest way. This step, while it must be taken quickly, must be done with great care, otherwise there may be two victims instead of one. This should be done in the case of a portable electric tool, light, appliance, equipment, or portable outlet extension by turning off the bulkhead supply switch or by removing the plug from its bulkhead receptacle. If the switch or bulkhead receptacle cannot be quickly located, the suspected electric device may be pulled free of the victim by grasping the insulated flexible cable to the device and carefully withdrawing it clear of its contact with the victim. Other persons arriving on the scene must be clearly warned not to touch the suspected equipment until it is unplugged. Aid should be enlisted to unplug the device as soon as possible. Where the victim is in contact with stationary equipment such as a bus bar or the contacts on a machine, he should be pulled free if the equipment cannot be quickly deenergized, or if considerations of military operation or ship survival prevent immediate shutdown of the circuits. The man can be quickly and safely cleared from his contact with the electricity by carefully applying the following procedures.

To save time, the equivalent of protective insulation for the rescuer must be improvised. For example, instead of taking time to hunt for a pair of rubber gloves for use in grasping the victim, the victim can be safely pulled free if conditions are dry by grasping him by slack in his clothing or by the leather of his shoes. Instead of hunting for a rubber mat on which to stand, such nonconducting materials as deck linoleum, a pillow, blanket, mattress, dry wood, or coil of rope will suffice. In no case during the rescue should any part of the rescuer's person directly touch hull metal or metal structure of furniture.

RESUSCITATION FOR ELECTRIC SHOCK

The following instructions on resuscitation were furnished by the Bureau of Medicine and Surgery.

Artificial resuscitation after electric shock includes artificial respiration to reestablish breathing, and external heat massage to reestablish heart beat and blood circulation.

To aid a victim of electric shock after removing him from contact with the electricity, immediately apply mouth-to-mouth artificial respiration.

If there is no pulse, immediately apply heart massage also.

Don't waste precious seconds carrying the victim from a cramped, wet, or isolated location to a roomier, dryer, frequented location.

If desired, breathe into victims mouth through a cloth or a handkerchief placed over victim's face. If assistance is available, take turns breathing into victim and in massaging his heart. See figure 4-16 parts 1, 2, and 3.

Cardiac Arrest
(Loss of Heart Beat)

If the subject has suffered an electric shock and has no heart beat, he will have a cardiac arrest. This can be demonstrated by finding a complete absence of any pulse at the wrist or in the neck. Associated with this the pupils of the eyes will be very dilated, respiration will be weak or stopped. The subject may appear to be dead. Under these circumstances severe brain damage will occur in four minutes unless circulation is reestablished by cardiac massage.

Closed Chest Cardiac Massage

This method has been adopted as practical and can be learned by anyone who is properly instructed, and requires only two hands. The object in closed chest cardiac massage is to squeeze the heart through the chest wall thereby emptying it to create a peripheral pulse. This must be done about 60 times each minute.

DIRECTIONS:

Place subject on his back; a firm surface, such as the deck, is preferred. Expose subject's chest.

Kneel beside victim; feel for lower end of subject's sternum (breastbone); place one hand across breastbone so the heel of hand covers the lower part; place second hand on top of the first so that the fingers point toward neck as in figure 4-16 part 3.

With arms nearly straight, rock forward so that a controlled amount of your body weight is transmitted through your arms and hands to the breastbone. The amount of pressure to apply will vary with the subject. With an adult subject the chest wall should be depressed 2 to 3 inches with each pressure application.

Repeat application of pressure about 60 to 80 times per minute.

An assistant should be ventilating the subjects lungs preferably with pure oxygen under intermittent positive pressure; otherwise with mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone you must concentrate on the massage until help can arrive.

Direct other assistants when available to keep checking the patient's pulse. Use the least pressure that will secure an effective pulse beat. The pupils of the victims eyes will become smaller when effective cardiac massage is being performed.

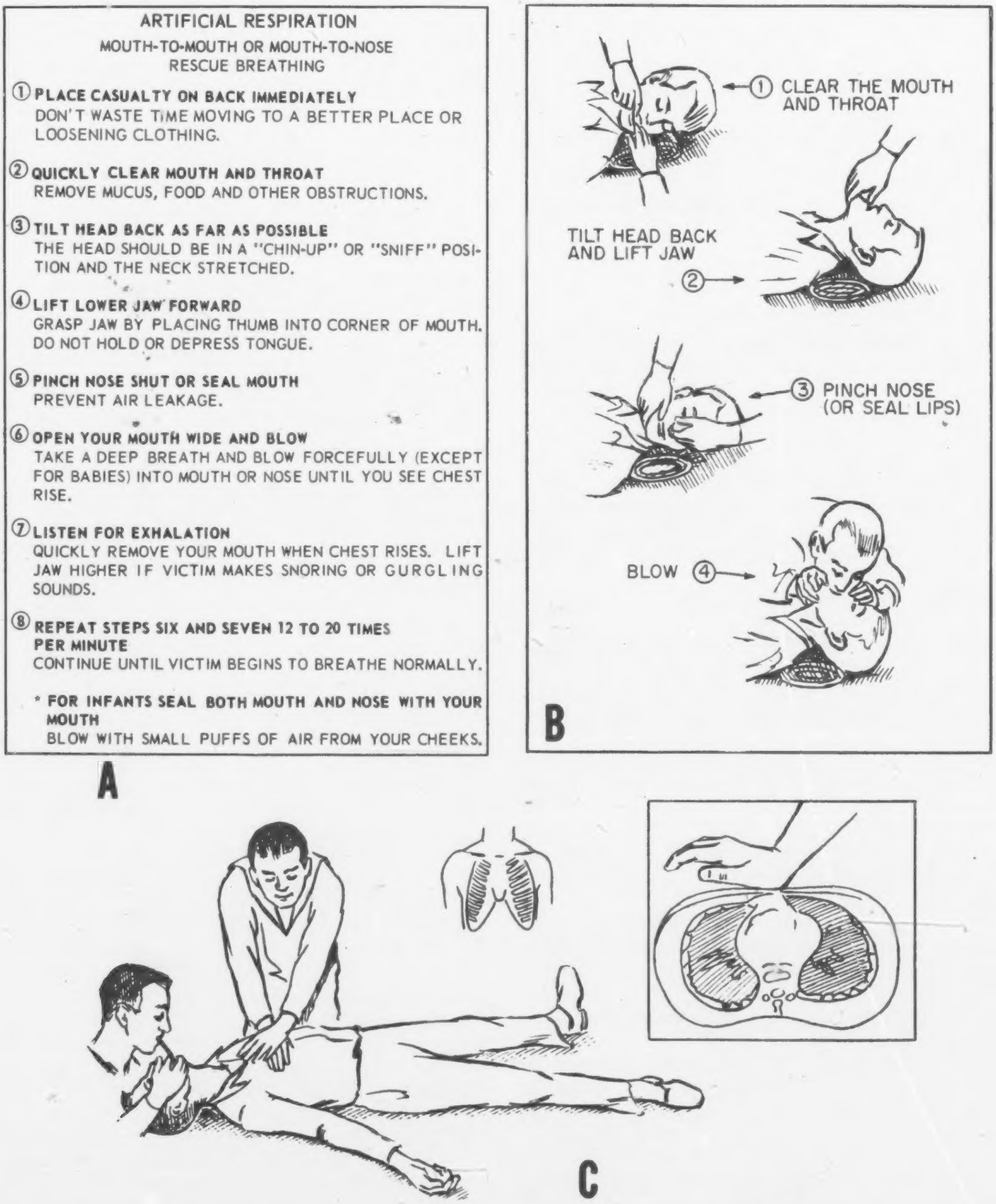
Pause occasionally to determine if a spontaneous heart beat has returned.

Precautions: Make every effort to keep the hands positioned as described in order to prevent injuries to the liver, ribs, or other vital organs. Since the heart cannot recover unless supplied with oxygenated blood, it is necessary to accompany cardiac massage with mouth-to-mouth artificial respiration. When there is only one operator, the cardiac massage must be interrupted every half minute or so to institute rapid mouth-to-mouth breathing for three or four respirations.

Safety precautions must always be observed by persons working around electric circuits and equipment to avoid injury from electric shock and/or short circuits caused by accidentally placing or dropping a metal tool, ruler, flashlight case, or other conducting article across an energized line. The arc and fire which can be so started on even relatively low voltage circuits may cause extensive damage to equipment and serious injury to personnel.

That the danger of shock from the 450-volt a-c ship's service system is reasonably well recognized by operating personnel is shown by relatively few reports of serious shock received from this voltage despite its widespread use. On the other hand, a number of shipboard fatalities have been reported due to contact with 115-volt circuits. Despite a fairly widespread but totally unfounded popular belief to the contrary, low voltage (115 volts and below) circuits are very dangerous and can cause death where the resistance of the body is lowered by moisture and especially when current passes through the chest.

After an accident has happened, investigation almost invariably shows that it could have been prevented by the exercise of simple safety precautions which are then posted for future guidance, but which never undo the consequences of the



ARTIFICIAL RESPIRATION

MOUTH-TO-MOUTH OR MOUTH-TO-NOSE RESCUE BREATHING

① **PLACE CASUALTY ON BACK IMMEDIATELY**
DON'T WASTE TIME MOVING TO A BETTER PLACE OR LOOSENING CLOTHING.

② **QUICKLY CLEAR MOUTH AND THROAT**
REMOVE MUCUS, FOOD AND OTHER OBSTRUCTIONS.

③ **TILT HEAD BACK AS FAR AS POSSIBLE**
THE HEAD SHOULD BE IN A "CHIN-UP" OR "SNIFF" POSITION AND THE NECK STRETCHED.

④ **LIFT LOWER JAW FORWARD**
GRASP JAW BY PLACING THUMB INTO CORNER OF MOUTH. DO NOT HOLD OR DEPRESS TONGUE.

⑤ **PINCH NOSE SHUT OR SEAL MOUTH**
PREVENT AIR LEAKAGE.

⑥ **OPEN YOUR MOUTH WIDE AND BLOW**
TAKE A DEEP BREATH AND BLOW FORCEFULLY (EXCEPT FOR BABIES) INTO MOUTH OR NOSE UNTIL YOU SEE CHEST RISE.

⑦ **LISTEN FOR EXHALATION**
QUICKLY REMOVE YOUR MOUTH WHEN CHEST RISES. LIFT JAW HIGHER IF VICTIM MAKES SNORING OR GURGLING SOUNDS.

⑧ **REPEAT STEPS SIX AND SEVEN 12 TO 20 TIMES PER MINUTE**
CONTINUE UNTIL VICTIM BEGINS TO BREATHE NORMALLY.

* **FOR INFANTS SEAL BOTH MOUTH AND NOSE WITH YOUR MOUTH**
BLOW WITH SMALL PUFFS OF AIR FROM YOUR CHEEKS.

A
① CLEAR THE MOUTH AND THROAT
TILT HEAD BACK AND LIFT JAW ②
③ PINCH NOSE (OR SEAL LIPS)
BLOW ④
B
C

4.224
Figure 4-16.—Artificial respiration and cardiac massage.

accident that has gone before. Always observe safety precautions and keep accidents from happening.

Always remember that:

1. Electricity strikes without warning.

2. Hurrying reduces caution and invites accidents.

3. Taking time to be careful saves time in the end.

4. Taking chances is an invitation to trouble.

5. If you do not know the safe way, it pays to find out before exposing yourself to danger.

6. Every electrical circuit, with but insignificant exceptions which definitely do not include circuits even as low as 35 volts and possibly even lower, is a potential source of danger and MUST BE TREATED AS SUCH.

7. Except in cases of emergency, never work on an energized circuit. It must be considered that the circuit is energized until a personal check has been made to see that the switch is opened and tagged, and the circuit has been tested with a voltmeter, or voltage tester.

CHAPTER 5

HYDRAULIC POWER DRIVES

Hydraulic power drives have been used with ordnance equipment for many years. Proof of their wide range of effectiveness is the fact that they have been used to train and elevate nearly all calibers of guns from 40-mm to 16" turrets. In addition, hydraulics are used to position and control such other ordnance equipment as rocket launchers, missile launchers, ammunition hoists, hoist cradles, rammer assemblies, empty case ejectors and extractors, and breech mechanisms.

We learned from our study of hydraulics in Fluid Power, NAVPERS 16193 (current revision), that one of the principal advantages of a hydraulic system over an all electric system is its ability to handle larger loads with uniform and flexible control despite rapid variations of the load.

In this chapter we will discuss two typical hydraulic power drive installations. The two selected for study are those used to control the movements of the 5"/38 twin gum mount ("K" type installation) and the one used with the 5"/54 single gun mount ("C" type installation). Many of the components used with either the "K" or "C" type hydraulic installations are common. Therefore we will list a glossary of commonly used hydraulic terms and review some of the basic hydraulic mechanisms explained in GMG 3&2, NAVPERS 10185 (current revision).

ACCUMULATOR: Device for storing hydraulic fluid under pressure. Accumulators function to (1) store power to allow system to meet short demands in excess of pump output, (2) smooth out surges and pulsations, and (3) meet low-capacity demands without operation of high-capacity pump (except intermittently to charge accumulator) (figure 5-1).

POPPET VALVE: Valve in the hydraulic end of a bag accumulator to prevent the synthetic bag from extending into the hydraulic manifold when there is no hydraulic fluid in the accumulator flask. (See poppet assembly in illustration of BAG TYPE ACCUMULATOR.)

DUMP VALVE: Valve which, when actuated, dumps hydraulic fluid trapped in an accumulator system, normally manually operated.

EXPANSION (HEADER) TANK: Tank, located above the hydraulic system, which provides space to allow for expansion and contraction of the fluid in a hydraulic system due to temperature changes. This tank also maintains a head of fluid in the system to prevent entry of air (figure 5-2).

AIR BREATHER: Device which allows air to enter or leave a hydraulic tank as the oil level changes. An air filter is normally installed in the breather. ((Refer to EXPANSION (HEADER) TANK.))

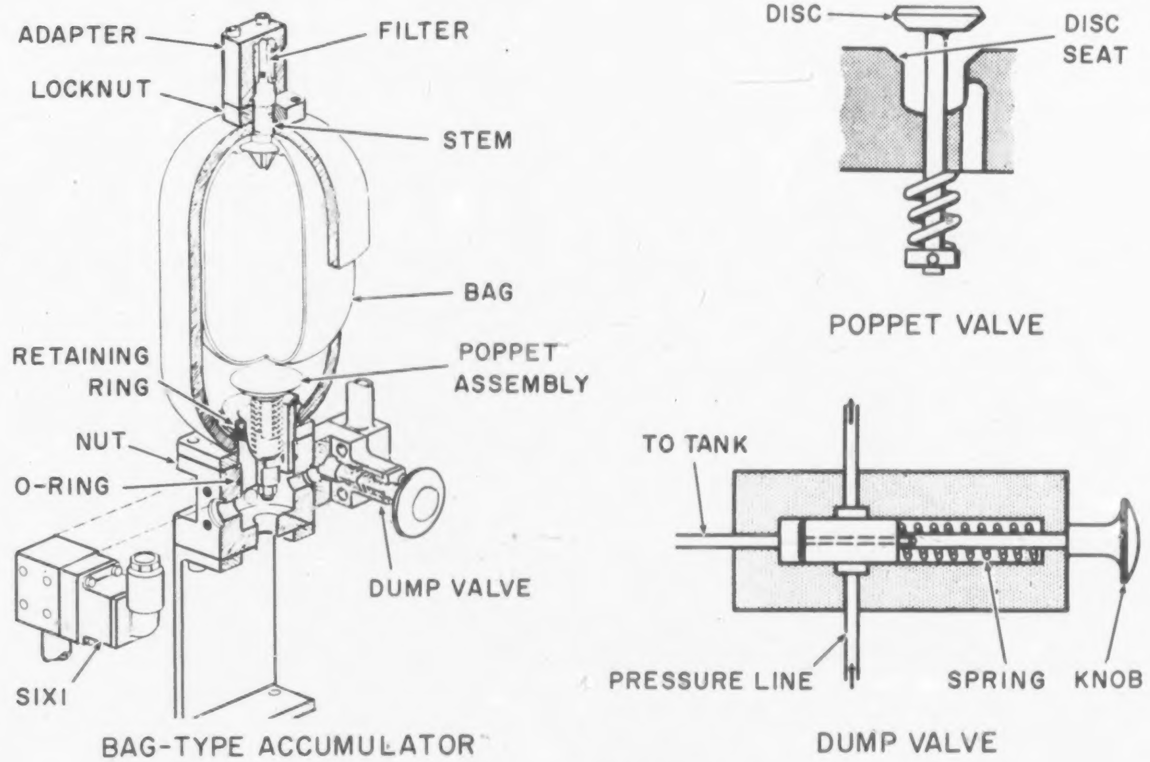
GLOBE VALVE: Manually operated valve that controls the flow of fluid by means of a plug, ball, or disk which can be raised from or lowered into a valve seat.

HEAD OF FLUID: Hydraulic fluid in a system that is maintained above the power drive level.

RESERVOIR (also called SUPPLY TANK): Power drive tank used to maintain a supply of working fluid which may be drawn from as needed. (figure 5-3).

DRAIN PLUG: Plug used to drain hydraulic fluid from a hydraulic system. (Refer to RESERVOIR (SUPPLY TANK).)

DRAIN LINES: Lines that return hydraulic fluid to the sump, supply, or header tanks.


ADAPTER
FILTER
LOCKNUT
STEM
BAG
RETAINING RING
POPPET ASSEMBLY
NUT
O-RING
DUMP VALVE
SIXI
BAG-TYPE ACCUMULATOR
DISC
DISC SEAT
POPPET VALVE
TO TANK
PRESSURE LINE
SPRING
KNOB
DUMP VALVE

33.183(83B):83.179
Figure 5-1.—Accumulator Assembly.

FILTER: Device for removal of dirt, sludge, and lint from a hydraulic fluid where the resistance to motion of such solids is in a tortuous path.

BYPASS VALVE: Valve used to let a volume of fluid bypass a hydraulic component. (Refer to FILTER.)

BAFFLES: Plates or partial plates which extend into hydraulic tanks to reduce sloshing and foaming and to aid in cooling the fluid.

SUMP TANK: Tank usually enclosed within a power drive reservoir or supply tank to ensure available space for receiver regulator drainage.

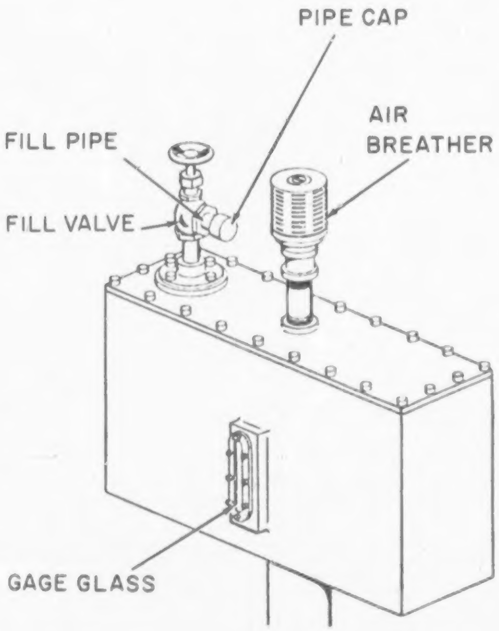
PISTON, PUMP, or MOTOR: Mechanical component of a pump or motor. The piston works in a cylinder and either moves the hydraulic fluid or is moved by the hydraulic fluid. (Refer to PARALLEL PISTON PUMP.)

PARALLEL PISTON PUMP (AXIAL PISTON PUMP): Pump in which pistons rotate on a shaft in such a way that the pistons are driven back and forth in their cylinders in a direction parallel to the shaft (figure 5-4).

CAB UNIT (Combination A-end and B-end): A-end and B-end which are located in the same housing and are separated by a valve plate.

A-END: Variable delivery pump. Device which converts mechanical energy to hydraulic energy. Normally driven by a constant-speed electric motor, provides continuously variable control of speed and direction of output. (Refer to CAB UNIT.)

B-END: Hydraulic motor. Device for converting fluid energy into mechanical energy.


PIPE CAP
AIR BREATHER
FILL PIPE
FILL VALVE
GAGE GLASS

83.178.1
Figure 5-2.—Expansion (Header) Tank.

TILT PLATE (or TILT BOX): Plate which is suspended by two trunnions and moved by the stroke piston(s) to control the output of a variable delivery radial piston pump. (Refer to CAB UNIT and PARALLEL PISTON PUMP.)

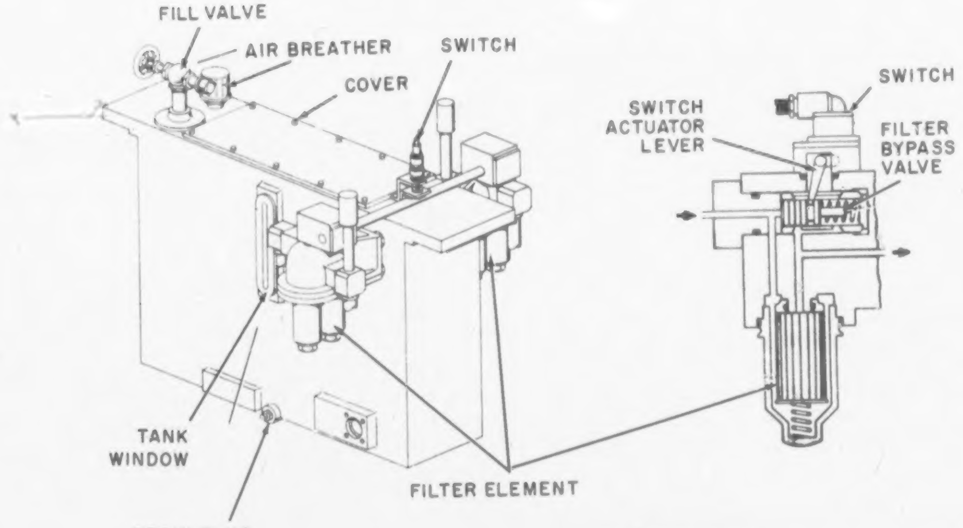
STROKE PISTON: Normally, a hydraulically controlled piston that controls the output of an axial piston variable delivery pump. (Refer to CAB UNIT.)

RELIEF VALVE: Valve which limits the maximum pressure applied to the portion of a hydraulic system to which it is connected.

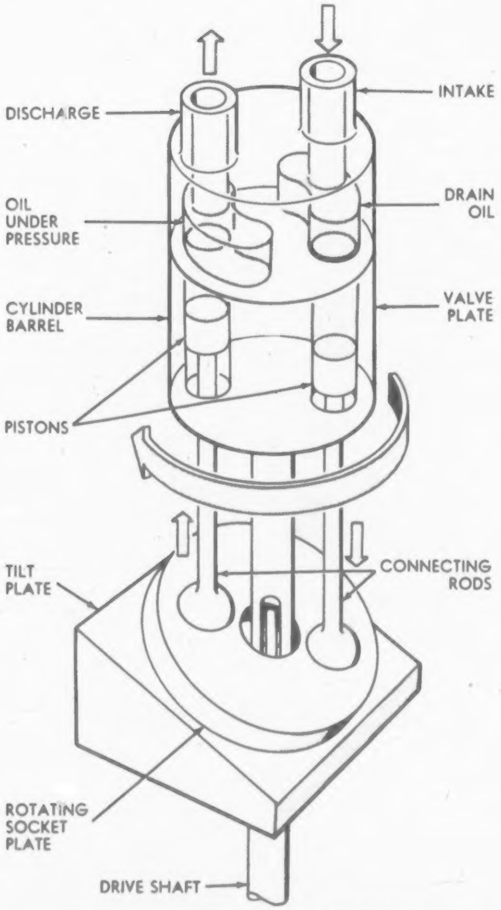
UNLOADING VALVE: Valve used in accumulator power drives which directs pump output to the accumulator or to tank, in accordance with system demand.

FLOW CONTROL VALVE: Valve which maintains a preset rate of flow regardless of pressure variations at its inlet or outlet (figure 5-5).

ORIFICE: Restriction in a fluid passageway that controls or limits the rate of fluid flow. (Refer to FLOW CONTROL VALVE.)


FILL VALVE
AIR BREATHER
SWITCH
COVER
SWITCH
SWITCH ACTUATOR LEVER
FILTER BYPASS VALVE
TANK WINDOW
FILTER ELEMENT
DRAIN PLUG

83.178.2:.176
Figure 5-3.—Reservoir (Supply Tank).



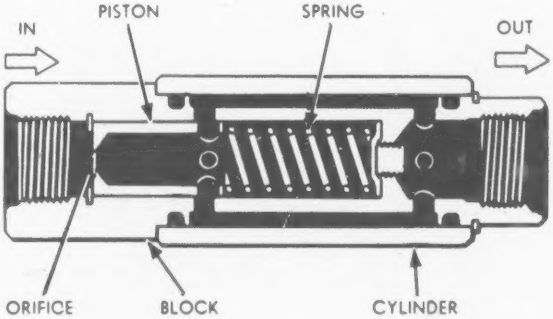
83.82(53C)
Figure 5-4.—Parallel Piston Pump.

RESTRICTION (also called CHOKE or ORIFICE): Device which produces a deliberate pressure drop in a line or passage by means of a reduced cross-sectional area. (Refer to FLOW CONTROL VALVE.)

PASSAGE: Machined hole or channel which lies in or passes through a hydraulic component and acts as a conductor of hydraulic fluid.

SURGE: Transient rise of hydraulic pressure in a hydraulic system.

SERVOSYSTEM: Closed-loop control system which may or may not include a hydraulic power drive.



83.179.4
Figure 5-5.—Flow Control Valve.

SERVOVALVE (also called PILOT VALVE or CONTROL VALVE): Valve in the hydraulic portion of a servosystem that is normally controlled by an electrical error signal and that originates the hydraulic control signal.

SERVO FLUID: Control pressure fluid in the hydraulic portion of a servosystem.

CONTROL FLUID (CONTROL PRESSURE): Hydraulic fluid (other than transmission fluid) under pressure used to control the operation of a hydraulic power unit.

SUPERCHARGE FLUID (sometimes called SUPERCHARGE PRESSURE): Refer to REPLENISHING FLUID.

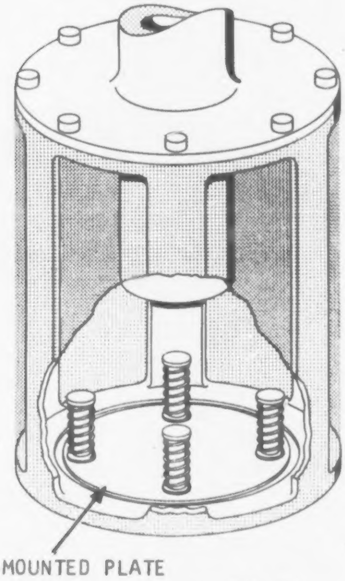
REPLENISHING FLUID (also called SUPERCHARGE FLUID): Fluid used to replace any volume loss in power drive transmission lines (lines between the A-end and the B-end).

TRANSMISSION FLUID: Hydraulic fluid located in the lines between the A-end and B-end.

UPSTREAM: Direction from which hydraulic fluid flows into a hydraulic component.

DOWNSTREAM: Direction in which hydraulic fluid flows away from a hydraulic component, such as a valve, cylinder, etc.

STRAINER: Device for removal of dirt, sludge, and lint from a fluid wherein the resistance to motion of such solids is in a straight line. A strainer is sometimes called a screen. (figure 5-6).


SPRING-MOUNTED PLATE

83.177
Figure 5-6.—Pump Strainer.

SLUDGE: Gummy deposit caused by hydraulic fluid breakdown, mainly due to oxidation.

OXIDATION: Chemical change in hydraulic fluid caused by oxygen which combines with the fluid during high temperature operation.

INHIBITORS (often called ADDITIVES): Chemicals added to hydraulic fluid to improve its ability to retard corrosion and foaming and to resist oxidation.

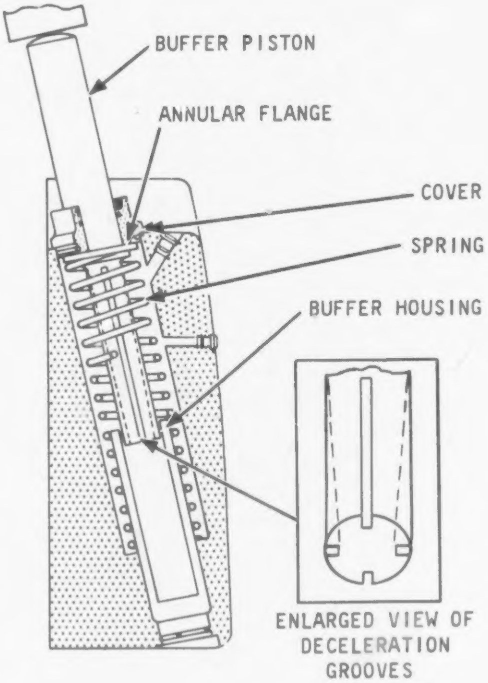
BUFFER: Mechanism used to retard or bring moving equipment to a smooth stop (figure 5-7).

DASHPOT: Device used to cushion the last portion of stroke and prevent metal-to-metal contact of pistons and plungers when they reach their ends of travel (figure 5-8).

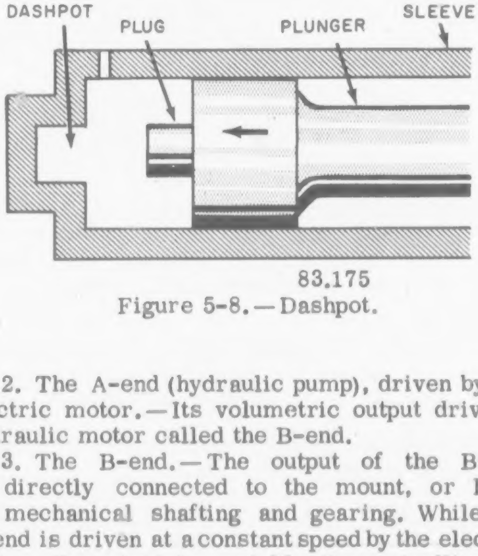
HYDRAULIC COMPONENTS

In its simplest form the hydraulic power drive consists of the following:

1. A prime mover.—This is an electric motor which drives a hydraulic pump.


BUFFER PISTON
ANNULAR FLANGE
COVER
SPRING
BUFFER HOUSING
ENLARGED VIEW OF DECELERATION GROOVES

83.173
Figure 5-7.—Buffer Assembly.


DASHPOT
PLUG
PLUNGER
SLEEVE

83.175
Figure 5-8.—Dashpot.

2. The A-end (hydraulic pump), driven by the electric motor.—Its volumetric output drives a hydraulic motor called the B-end.

3. The B-end.—The output of the B-end is directly connected to the mount, or load, by mechanical shafting and gearing. While the A-end is driven at a constant speed by the electric motor, its output is variable. By controlling the

output of the A-end, the direction and speed of the B-end and, hence the direction and speed of mount motion, can be controlled.

4. A means of introducing a signal to the A-end to control its output. (The control equipment for hydraulic power drives will be covered in the following chapter).

5. The mechanical shafting and gearing that transmits the B-end output to the train and elevation drive pinions.

PUMPS

One basic element, the hydraulic pump, is found in all hydraulic power drives. Pumps furnish fluid pressure for many purposes such as lubricating, cooling, replenishing hydraulic transmissions, and for control of hydraulic components. For our purposes these pumps are divided into two categories: constant and variable delivery. We will briefly review three common pumps that belong to one or the other of these categories.

CONSTANT DELIVERY PUMPS

Pumps of this type—either gear, vane, or piston, are designed to deliver a definite quantity of liquid during each revolution.

Rotary Gear Pump

The rotary gear pump is a constant delivery type pump. Three kinds of true gears may be used in its construction: spur, helical, and herringbone. Its operation is basically the same in all of its variations. Figure 5-9 shows a simple rotary gear type pump.

One of the gears is directly driven by a source of power. Motion is imparted to the other gear by the meshing of the two at the center of the pump chamber. There are close clearances between the gear teeth and the pump casing, and between the teeth of the gears at their point of contact, where they form a continuous, fluid-tight joint. As the gears rotate in the direction indicated by the arrows, liquid is trapped in turn between each pair of teeth and the casing, and carried away from the intake chamber. Pressure is therefore lowered in the intake chamber so that liquid flows into it from the source of supply. The close meshing of the teeth at the center keeps liquid from passing back to the input chamber.

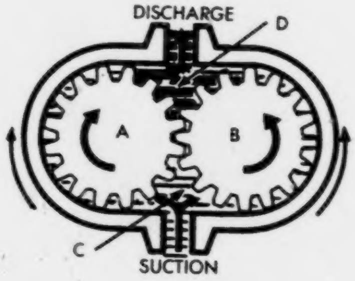
Axial Piston Pump

An axial piston pump (sometimes called parallel piston pump) may be of either the constant delivery or the variable delivery type. We will review both types, and later show particular applications of each.

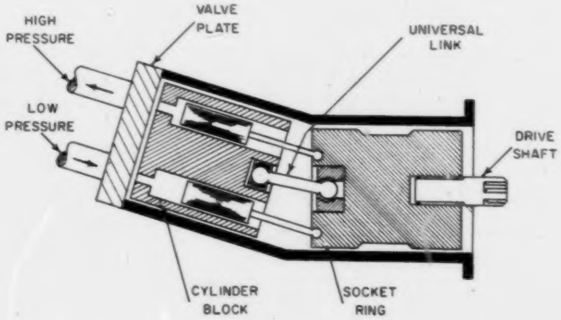
The constant delivery type is shown in figure 5-10. Consider all parts to the right of the valve plate to be rotating elements driven by an external force through the drive shaft.

The cylinder block, containing bores in which the pistons work, is held against the valve plate by spring pressure. Notice that there is built into this type of pump a fixed, permanent angle of tilt. The universal link allows the cylinder block and socket ring to be rotated, but the angular displacement between the two will remain fixed.

Due to the angle of tilt, a rotary motion of the assembly drives the pistons in and out of their



38.108
Figure 5-9.—Rotary Gear Pump.



53.68
Figure 5-10.—Constant Delivery Axial Piston Pump.

cylinders in a reciprocating (axial) motion. This causes oil to be forced out of the cylinders as the pistons push in toward the valve plate. Oil will be drawn into the cylinders as the pistons are drawn outward. Two sausage-shaped ports in the valve plate, called valve ports, are arranged so that oil is ported between the pistons and the two transmission lines. As the angle of tilt is permanent, one line remains the output line and the other the return line at all times during the pump's operation.

The portions of the valve plate between the two valve ports are called lands. They are positioned so that they coincide with the end of stroke of each of the reciprocating pistons.

Axial piston pumps are constructed so as to contain an odd number of pistons. If an even number of pistons were used, the discharging flow would be pulsatory.

VARIABLE DELIVERY PUMPS

The most widely used variable delivery pump is the axial piston type. Its characteristics make it especially applicable as the A-end in hydraulic power drives. Its operation is similar to that of the pump just described. The difference is that the angle of tilt between the socket ring and the cylinder block is variable, figure 5-11.

If the socket ring were tilted 20° from the cylinder barrel, the pistons would move in and out of their cylinders a definite length. Output of the pump would be a definite amount per revolution of the assembly. If the socket ring tilt were changed to 10°, the axial movement of the pistons would be reduced and the output halved. Bringing the socket ring to its zero position (no tilt) would result in no flow of oil. By moving the socket ring past neutral, the intake and output portions of the cycle are reversed. Also, the flow of oil in the transmission lines will also be reversed.

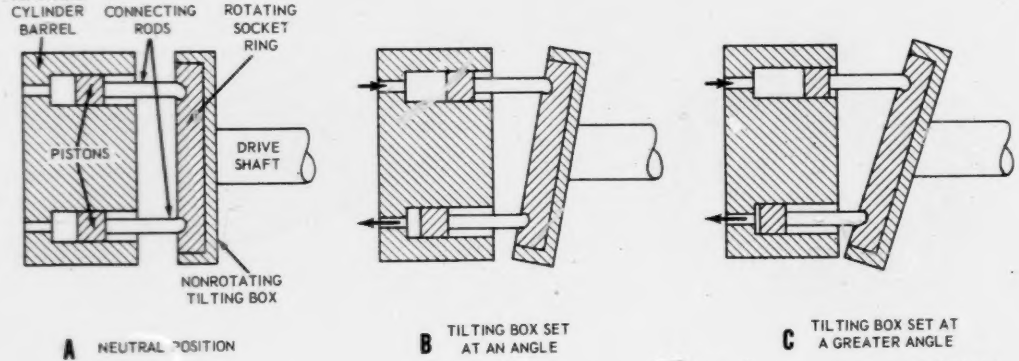
Types of Axial Piston Pumps

Varieties of the axial piston pumps just described are the Waterbury, Northern, and Vickers.

The Waterbury and Northern pumps act according to the same principle and are similar in most details of construction. The Vickers pump, while employing the same principle as the other two, differs in construction. The two most important differences are:

1. The Waterbury and Northern pumps control the volume and direction of flow by changing the degree and direction of tilt of the A-end tilting box, which encloses the socket ring. In the Vickers pump this is done by pivoting the cylinder block to either side of a neutral position. The cylinder block and valve plate are housed in a casting called a yoke. The yoke is swung on a pair of hollow pintles.

2. In the Waterbury and Northern pumps, the main transmission lines are directly connected to the valve plate. In Vickers units the valve plate moves from side to side, and a direct connection cannot be made. So the yoke is cast



147.111

Figure 5-11.—Diagram Showing How Tilting Box Position Affects Position of Pistons.

with passages leading from the cylinders to the hollow pintles. The fluid flows in through one pintle, through the yoke and cylinder block, out through another passage in the yoke, then out through the other pintle.

Type "K" Installation

A typical "K" type hydraulic power drive is used with the 5"/38 twin gun mount. Two separate hydraulic installations are used to control the gun mount in train and elevation. These systems differ only in size and in minor details so only one, the train power drive, will be described.

GENERAL DESCRIPTION

The basic components of the train power drive are shown in figure 5-12. The electric drive motor is constructed with drive shafts at both ends. The forward shaft drives the A-end pump through reduction gears. The after shaft is coupled through reduction gears to the auxiliary pumps.

The ports in the A-end valve plate are connected to like ports in the B-end valve plate by large copper pipes. Oil pumped by the A-end causes rotation of the B-end. Output of the B-end is connected by shafts and gears to the training circle of the mount.

Let's examine each major component in detail to understand its construction and operation.

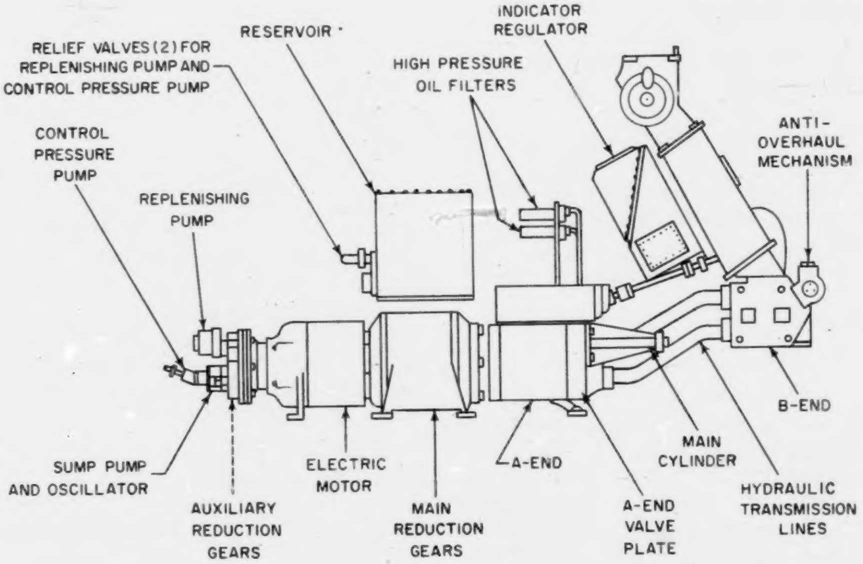
Electric Motor

The prime mover, or electric drive motor, is of the squirrel cage induction type. The motor drives the A-end of the hydraulic power transmission. Through reduction gears, it also drives the replenishing pump, control pressure pump, and the sump pump and oscillator.

A motor controller with its associated push-button stations starts and stops the electric motor and gives protection against overload and undervoltage. The controller is located in the upper handling room except on mounts having a ready-service rotating ring which would bar access to the controller. In such a case the controller is mounted outside but near the handling room.

Main Reduction Gear

The A-end pump is designed to operate at a speed of approximately 900 revolutions per minute. Since this speed is much lower than that


INDICATOR REGULATOR
RESERVOIR
RELIEF VALVES (2) FOR REPLENISHING PUMP AND CONTROL PRESSURE PUMP
HIGH PRESSURE OIL FILTERS
ANTI-OVERHAUL MECHANISM
CONTROL PRESSURE PUMP
REPLENISHING PUMP
B-END
MAIN CYLINDER
SUMP PUMP AND OSCILLATOR
ELECTRIC MOTOR
A-END
HYDRAULIC TRANSMISSION LINES
AUXILIARY REDUCTION GEARS
MAIN REDUCTION GEARS
A-END VALVE PLATE

53.69

Figure 5-12.—Train Power Drive (Type "K" Installation).

of the electric motor, it is necessary to reduce the speed of rotation between the A-end and the electric motor. This speed reduction is performed by the planetary (main) reduction gear (fig. 5-13). The main reduction gear is mounted in a housing between the power motor and the A-end. A helical gear, called the sun gear, is mounted on the output shaft of the motor and three helical gears, known as planet gears, are grouped 120 degrees apart on a rotating member (fig. 5-13).

The planet gears mesh with the sun gear and with a large fixed gear mounted in the reduction gear housing. As the sun gear rotates, driven by the electric power motor, the planet gears also rotate about the inside circumference of the fixed gear carrying with them the rotating member in which they are mounted. The A-end main shaft (reduction gears output shaft) is spline mounted in the rotating member which drives the output shaft at a fixed reduced ratio. A heavy flywheel, mounted in the drive shaft of the power motor, prevents any sudden change in speed of the power motor. Any flywheel is used to store energy. This energy in the flywheel helps to prevent changes in the speed of the electric motor due in part to the reaction through the power unit to the shock of gunfire (inertia) when the equipment is in any type of power control.

HYDRAULIC TRANSMISSION

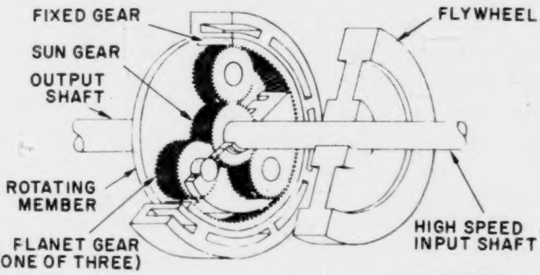
The hydraulic transmission system includes the following components:

1. Electrically driven variable delivery hydraulic pump A-end.
2. Main cylinder, containing the stroke control shaft. (This assembly is used in controlling the tilt of the A-end.)
3. B-end, a fixed displacement hydraulic motor.
4. Auxiliary pumps.

A-End

The train A-end is shown in figure 5-14A. It is an axial piston, variable delivery pump. The direction and speed of its output controls the direction and speed of rotation of the B-end. It is driven at a constant speed by the electric motor through the main reduction gears. The A-end housing encases and supports the rotating assemblies of the pump.

The cylinder barrel is keyed to the main shaft. It contains nine cylinder bores. It is held against the valve plate by a spring. The pistons operating in the bores of the cylinder barrel are ground and lapped to a smooth working fit. A hole drilled through the front of each piston admits oil for lubricating the connecting rod ends.



2.211(53C)
Figure 5-13.— Planetary Reduction Gears.

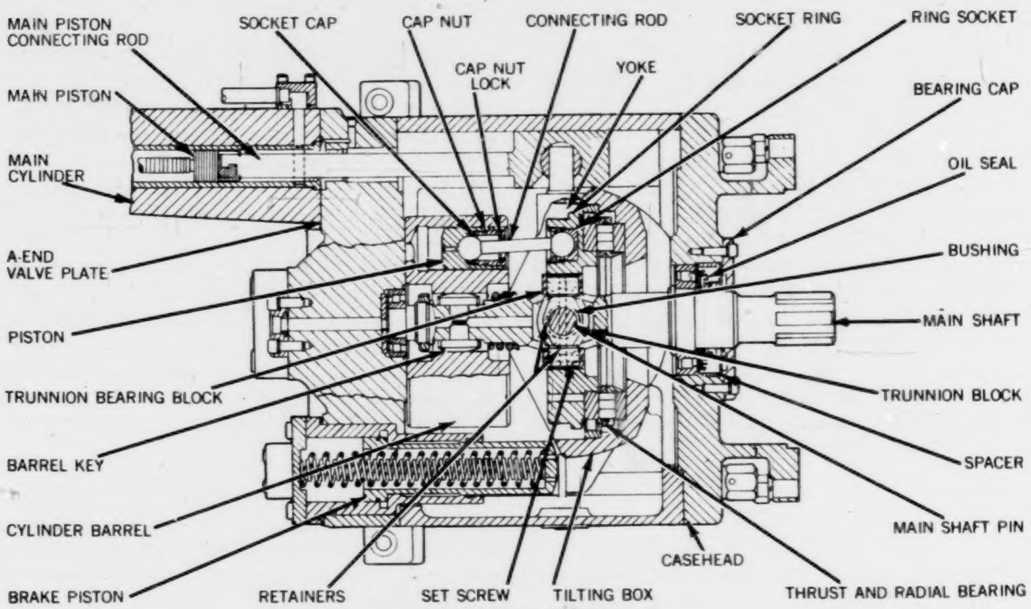
The connecting rods with ball-shaped ends connect the pistons to the socket ring. Each connecting rod is drilled throughout its length to admit oil from the interior of the cylinder to the two end bearings.

The socket ring is a circular piece containing nine sockets in which the connecting rod ends are secured. A collar projects around the central opening on the rear surface of this ring. A radial bearing fits around this collar and, in turn, acts as an outer roller path for a thrust bearing. A circular plate on the tilting box serves as an inner roller path for the thrust bearing.

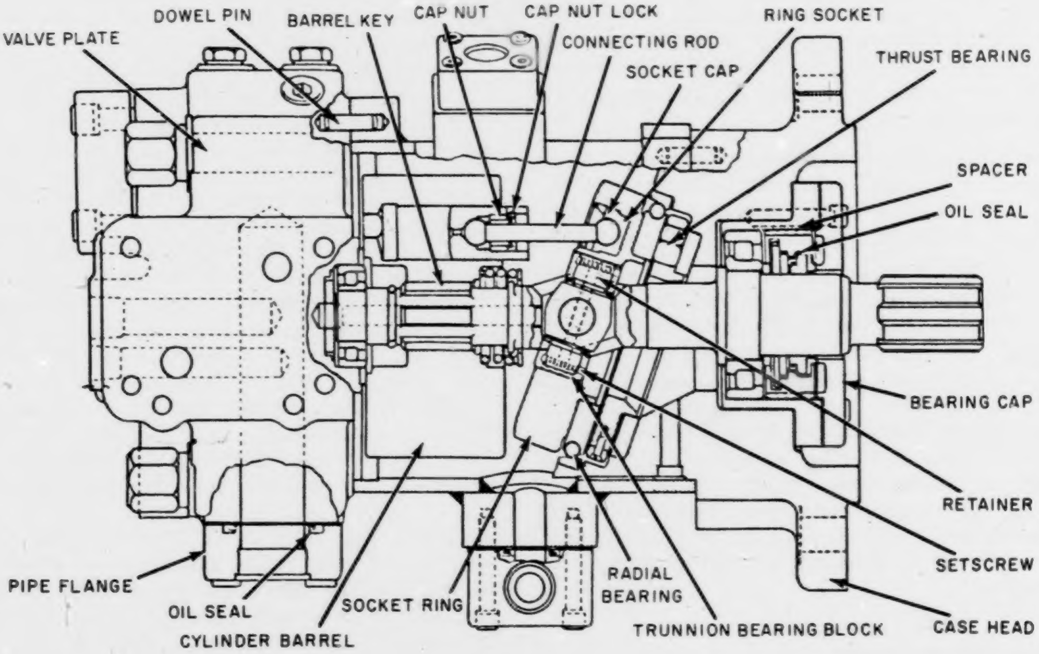
The socket ring is mounted on a trunnion block that rides inside the yoke of the main shaft. A pin, secured to the trunnion block, passes through the main shaft and rotates in bushings in the shaft. This arrangement acts as a universal joint for the socket ring. The trunnion block, and therefore the attached socket ring, is free to rotate about the axis of the pin. This movement permits the tilting box to control the length of stroke of the pistons.

The tilting box encloses the socket ring and provides a means of varying the angle of the socket ring in relation to the main shaft, and thus varying the length of the piston stroke from zero to maximum. The tilting box is a trunnion-mounted casting located inside the A-end housing.

The tilting box can be rotated on its trunnions through a limited arc. When the tilting box is in a plane perpendicular to the main shaft,


MAIN PISTON CONNECTING ROD
SOCKET CAP
CAP NUT
CONNECTING ROD
SOCKET RING
RING SOCKET
CAP NUT LOCK
YOKE
MAIN PISTON
BEARING CAP
MAIN CYLINDER
OIL SEAL
A-END VALVE PLATE
BUSHING
PISTON
MAIN SHAFT
TRUNNION BEARING BLOCK
TRUNNION BLOCK
BARREL KEY
SPACER
CYLINDER BARREL
MAIN SHAFT PIN
CASEHEAD
BRAKE PISTON
RETAINERS
SET SCREW
TILTING BOX
THRUST AND RADIAL BEARING

(A) A-END PUMP


VALVE PLATE
DOWEL PIN
BARREL KEY
CAP NUT
CAP NUT LOCK
CONNECTING ROD
SOCKET CAP
RING SOCKET
THRUST BEARING
SPACER
OIL SEAL
BEARING CAP
RETAINER
SETSCREW
PIPE FLANGE
OIL SEAL
CYLINDER BARREL
SOCKET RING
RADIAL BEARING
TRUNNION BEARING BLOCK
CASE HEAD

(B) B-END MOTOR

53.70(53C)

Figure 5-14.—Hydraulic Pump and Motor.

it is in the neutral position and there is no reciprocating motion of the pistons in their cylinders. Angular displacement from the perpendicular plane governs the output of the A-end. Movement of the tilting box is directly controlled by the stroke control shaft.

The valve plate is a stationary member, and constitutes one end of the A-end case. The inner face of the valve plate has a finished surface against which the cylinder barrel rotates. This surface is provided with two semiannular valve ports which receive and discharge oil from the cylinders. The portions of the valve plate surface between the ports, called lands, are used to separate the driving oil from the returning oil.

The active system piping consists of two large copper pipes leading from the A-end valve plate ports to the B-end.

B-End

The B-end is similar in construction to the A-end except that the tilt of the socket ring is fixed in the B-end. Oil under pressure from the A-end will enter one of the grooves of the B-end valve plate and exert a force against the surface of the B-end pistons. The force against the face of the pistons will result in a thrust component causing a turning force to be imparted to the socket ring (fig. 5-14B).

The socket ring is mounted on an output shaft through a universal joint, and rides on roller bearings on a roller track that is positioned at a 20° fixed angle in relation to the output shaft.

As the B-end pistons must each make a full stroke for every revolution of the output shaft, speed of the B-end, and hence the speed at which the guns are elevated and trained, is directly proportional to the angular displacement of the A-end tilting box from its neutral position.

The output shaft of the B-end motor is connected to the elevating and training pinions through a mechanical system of gearing and shafting. To compensate for misalignment of the B-end shaft and the final drive gearing, they are connected by flexible or self-aligning type couplings.

Auxiliary Pump Cluster

The auxiliary reduction gears are flange-mounted at the rear of the electric power motor. Three important pumps are driven by the motor through these gears (fig. 5-12).

REPLENISHING PUMP.—This pump is a spur gear pump driven at a constant speed by the electric motor through the auxiliary reduction gear. Its purpose is to replenish oil for the active system of the power drive.

The pump draws oil from the reservoir and discharges it at a regulated pressure to the B-end valve plate.

The discharge of the pump is held at a constant pressure (normally between 25 and 50 psi) by the action of a hydracone relief and dump valve. Normally, because the capacity of the pump exceeds replenishing demands, the relief valve is continuously dumping some of the oil to exhaust. This valve is adjustable.

SUMP PUMP AND OSCILLATOR.—This pump is also driven by the auxiliary reduction gears. Its purpose is twofold. It pumps leakage oil, which will collect in the sump of the indicator regulator, to the expansion tank.

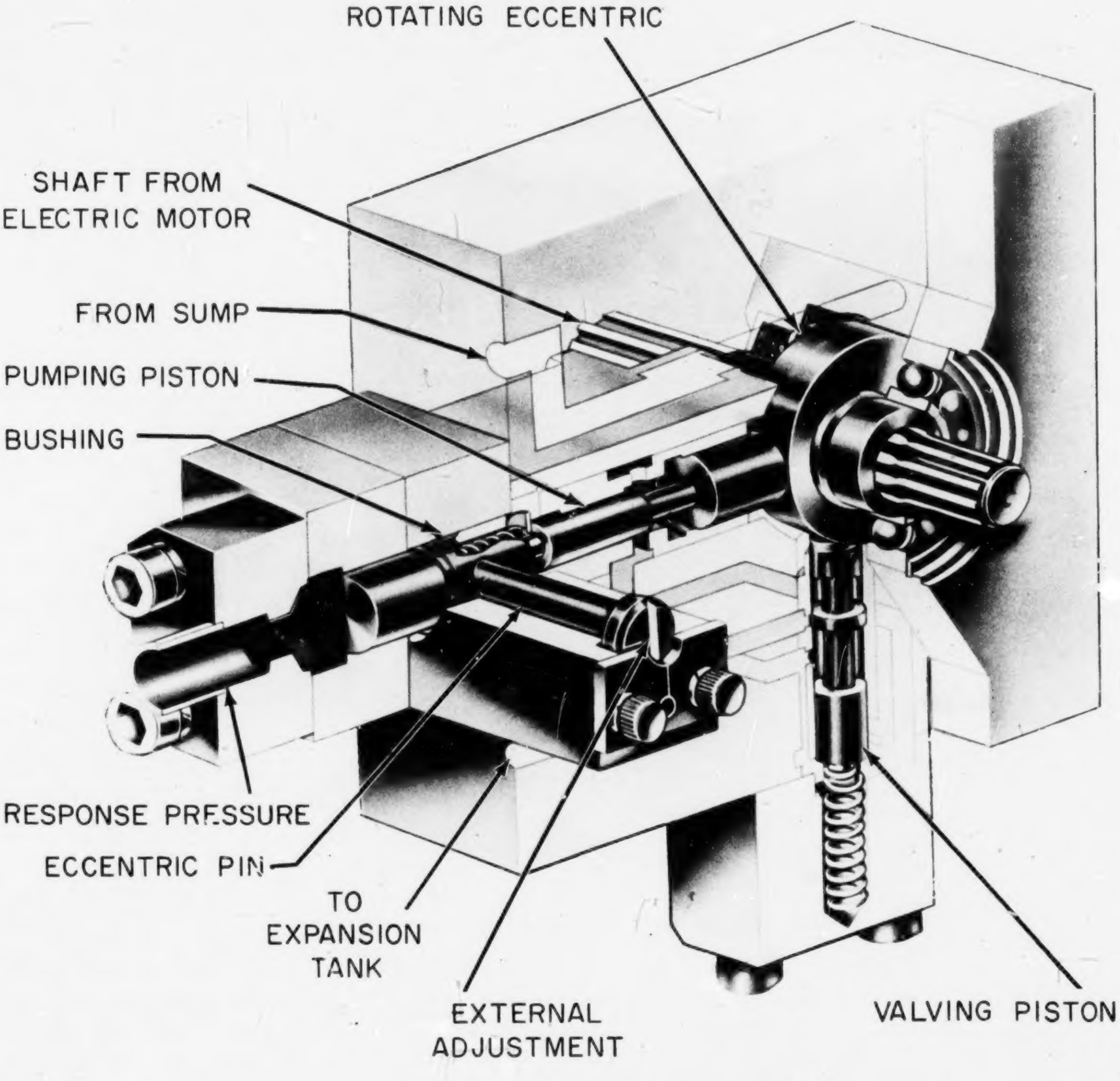
Its other function is to transmit a pulsating effect to the oil in the response pressure system. Oscillations in the hydraulic response system help eliminate static friction of valves to make the hydraulic control respond faster.

A cutaway drawing of this pump is shown in figure 5-15. The pumping piston has an extension of reduced diameter, which operates through a bushing. The piston is spring loaded, ensuring constant contact with the rotating eccentric. The extension of the pumping piston through the bushing operates the second piston, which provides the oscillation to the response pressure system. Lengthwise movement of the bushing varies the amount of oscillation produced. An eccentric pin controlled by an external adjustment positions the bushing to obtain a satisfactory standstill condition with a minimum of oscillation.

The valving piston and the pumping piston act in conjunction to port oil from the sump of the indicator regulator to the pumping piston where it is pumped into the expansion tank.

CONTROL PRESSURE PUMP.—The remaining pump driven by the auxiliary reduction gears is the control pressure pump (fig. 5-16). Its function is to supply high pressure oil for the hydraulic control system, brake pistons, lock piston (at the anti-overhaul valve block), and the hand-control clutch operating piston.

The control pressure pump is an axial piston pump, described earlier in the chapter. It is


ROTATING ECCENTRIC
SHAFT FROM ELECTRIC MOTOR
FROM SUMP
PUMPING PISTON
BUSHING
RESPONSE PRESSURE
ECCENTRIC PIN
TO EXPANSION TANK
EXTERNAL ADJUSTMENT
VALVING PISTON

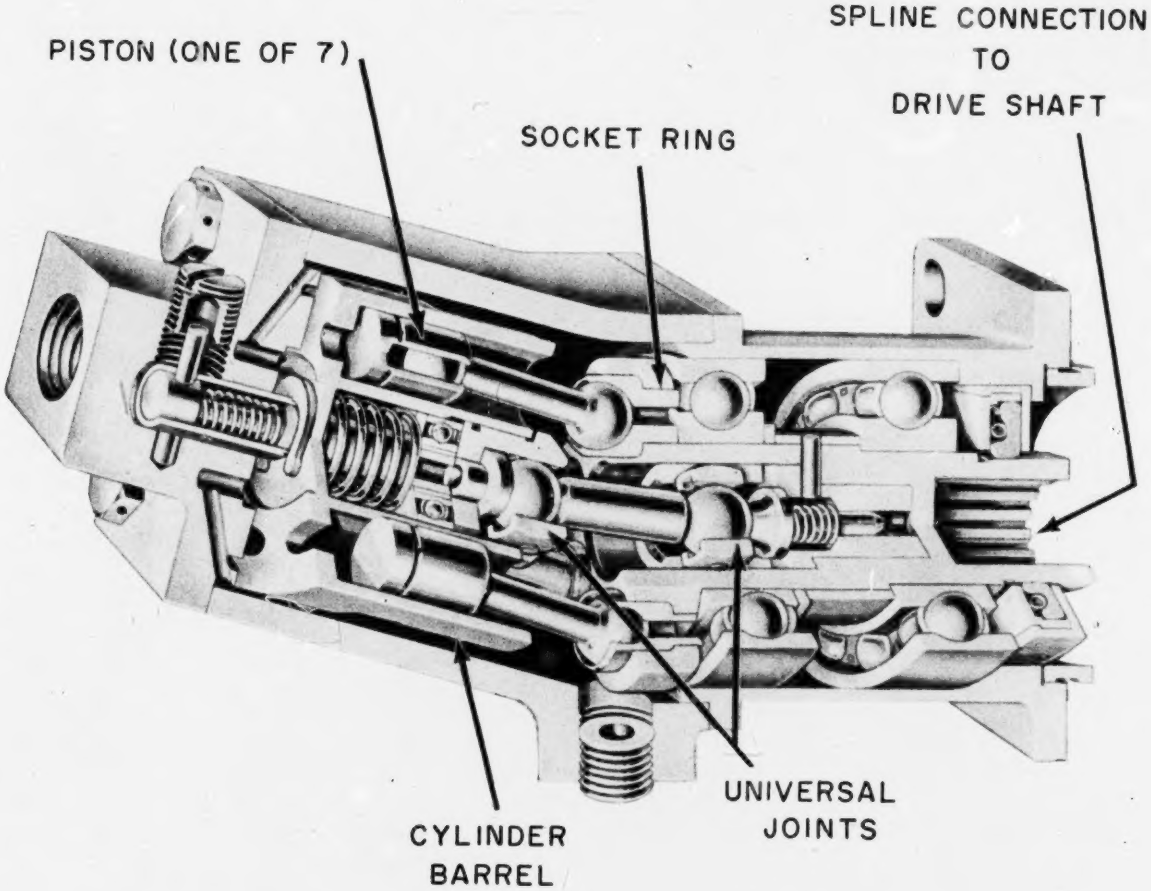
53.71
Figure 5-15.—Sump Pump and Oscillator.

similar to the A-end pump except that the angle of tilt is permanently fixed. Consequently, the pump produces a constant volume output.

To limit the pressure of the pump output to operating pressures, an adjustable relief valve, identical with that of the replenishing pump relief valve, is used. Pump pressure can be measured by inserting a gauge in the plug hole located in the relief valve block. Changing the pressure is accomplished at the relief valve by a simple screw type adjustment.

CONTROL

Control, as it pertains to the indicator regulator and the handwheel bracket, will be studied



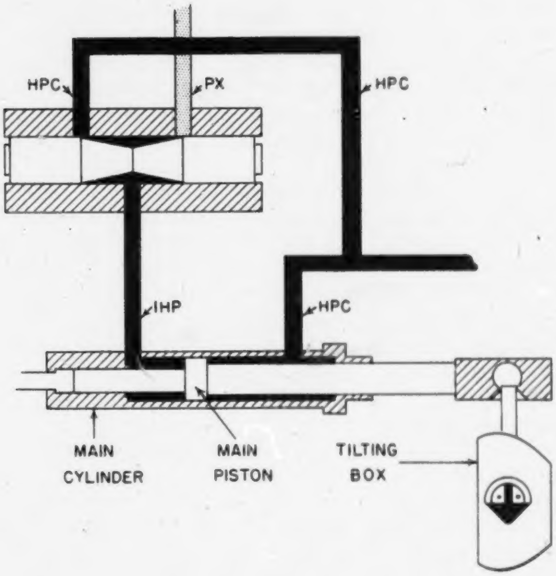
53.72
Figure 5-16.—Control Pressure Pump.

in detail in the following chapter. For the purposes of this chapter, we can say that it constitutes the relationship between the stroke control shaft and the tilting box. The stroke control shaft is physically located in the main cylinder (fig. 5-17). It is the link between the hydraulic followup system and the power drive itself.

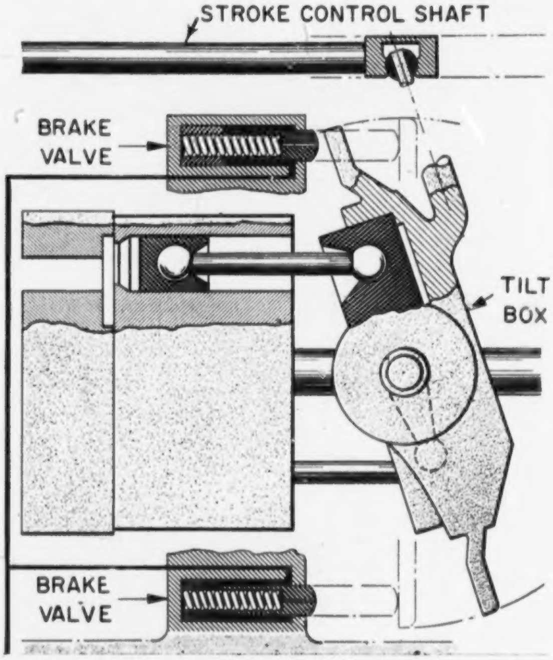
In hand control, the tilting box is mechanically positioned by gearing from the handwheels through the A-end control unit. In local and automatic control, the tilting box is positioned by the stroke control shaft. This shaft is connected at one end to the tilting box. On the other end, operating in the main cylinder, is the main piston. Intermediate high pressure (IHP) is transmitted to one side of the piston. The other side of the main piston is connected to high pressure (HPC), which is held constant at 1000 psi. Since the area upon which HPC acts is exactly one-half the area upon which IHP acts, the main piston will be held fixed in one position when IHP is one-half of HPC. Whenever IHP varies from its normal value of one-half HPC, because of action of various control valves, the main piston will move, and thus cause movement of the tilting box.

BRAKE VALVES

An assembly consisting of two brake valves (pistons) acts to force the tilting box to its zero position whenever control pressure is released



53.73
Figure 5-17.—Main Cylinder Assembly.



53.74
Figure 5-18.—Brake Valves.

(fig. 5-18). These spring-loaded pistons are normally held back against the spring pressure to allow the tilting box free movement in hand, local, or automatic control. This is done by oil pumped at high pressure from the control pressure pump. When oil pressure drops, the pistons are moved by their springs to center the tilting box. The brake valves are adjustable in both the train and elevation drives, but by different means.

In the train power drive, shims are provided on the valve plate end of the brake pistons. These shims permit adjusting the pistons to bring the tilting box to an obsolute zero position when they are released.

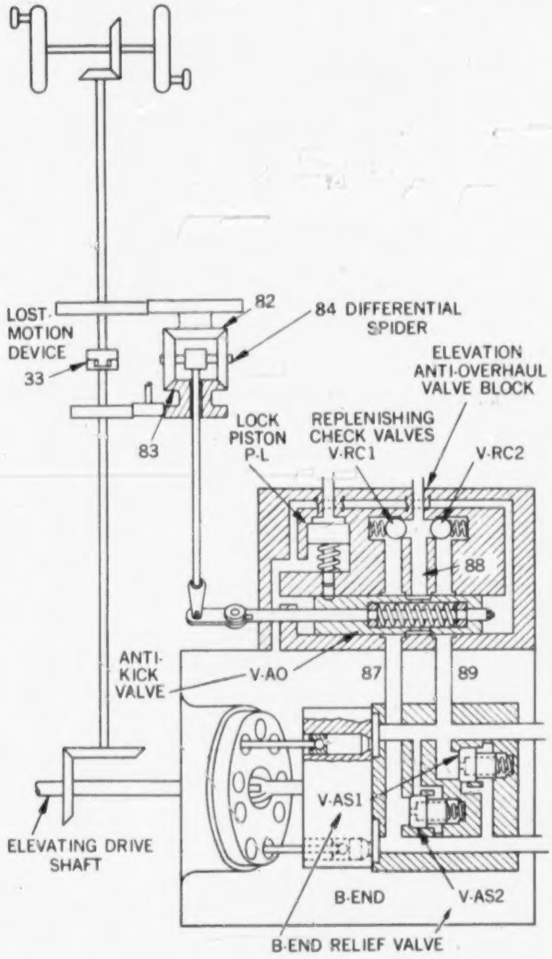
This function is accomplished in the elevation power drive by a creep eccentric adjustment. This is an eccentric camshaft fitted into an opening in the bottom of the brake piston and stroke shaft assembly housing. The creep eccentric acts primarily as a stop for the brake pistons. By adjusting the creep eccentric, you can cause the brake pistons to bring the tilting box to the exact neutral position, and thus prevent the mount from creeping while the brake pistons are released.

ANTI-OVERHAUL MECHANISM

When the mount is in manual control, the A-end is at neutral so that there can be no oil flow between the two ends of the hydraulic transmission system. The manual drive, however, is connected to the output shaft of the B-end. When the mount moves, the B-end rotates and acts as a pump. The pressure thus built up would cause a hydraulic block, preventing movement of the mount if not relieved.

Anti-Overhaul Action

This pressure is relieved by the action of the anti-overhaul valve which transfers this oil flow from one side of the B-end to the other. It also prevents the flow of oil in the opposite direction when the direction of gun movement is reversed by gunfire. This prevents gunfire shock from being transferred to the handwheels. A diagram of the anti-overhaul mechanism is shown in figure 5-19.



53.75
Figure 5-19.—Anti-overhaul Mechanism.

The valve block is secured to the B-end unit. It houses the replenishing check valves, the lock piston, and the anti-overhaul valve. When the mount is in any type of control, other than manual, the anti-overhaul valve is locked in its neutral position by the lock valve.

The anti-overhaul valve is connected to the handwheel drive through the lost motion device and a differential. Initial movement of the handwheels causes the upper section of the lost motion device and the primary gear of the differential to rotate before the lower section of the lost motion device. During this time the spider of the differential rotates with the primary gear and positions the anti-overhaul valve. After the lost motion has been taken up, the lower section of the lost motion device begins to turn, moving the mount. The spider stops moving and remains stationary as long as the mount is being driven in the same direction. If handwheel movement is reversed, the position of the anti-overhaul valve is reversed.

Now, suppose the mount is placed in manual control and the handwheels are rotated. During the first small amount of handwheel rotation, the anti-overhaul valve is shifted, opening either line 87 or 89 to chamber 88 (fig. 5-19). Oil pumped by the B-end will flow through one of the lines, through the anti-overhaul valve, through chamber 88, and lift the check valve of the other line. It enters and flows through the other line and returns to the B-end.

Should gunfire cause a kickback, the B-end immediately acts to reverse the direction of oil flow. The check valves, however, will allow a flow of oil into lines 87 and 89, and not out. Therefore, reversal of the B-end is hydraulically blocked, and the B-end will take the shock of kickback. If kickback reaction is extremely violent, the B-end relief valve may be forced momentarily to open one side of the active system to the other and thereby prevent damage to the equipment.

Should the mount tend to overhaul the handwheel movement as a result of gunfire, the lower section of the lost motion device momentarily rotates faster than the upper section. This causes the secondary gear to rotate faster than the primary gear. The spider will then rotate in a direction opposite to its original one, moving the anti-overhaul valve in the opposite direction. This creates a hydraulic block, as for kickback, and prevents further overhaul rotation of the B-end. As a result, the upper part of the lost motion device cannot be driven by gun overhaul, and the reaction cannot reach the hand wheels.

The anti-overhaul valve is adjustable in both train and elevation power drives, but by different methods. In either drive the check for error in adjustment is the same. With the selector controls set at MANUAL and LOW, rotate the handwheels slowly in both directions. If there is an appreciable error in adjustment, the resistance of the handwheels will differ greatly for the two directions of rotation, and the output will be rough in one direction. In this case, adjust the anti-overhaul valve linkages in accordance with the instructions in OP 805.

THE 5"/54 MOUNT POWER DRIVE

Although some 20 years of engineering advances separate the 5"/38 twin mount drive and the 5"/54 Mk 42, you will see that essentially they are still very much the same. The more significant differences are in the control equipment for the two drives. You will be able to compare these differences after studying the chapter that follows on control equipment for hydraulic power drives.

The train and elevation drives of the 5"/54 Gun Mount Mk 42 are separate electric-hydraulic power systems which, in response to electrical gun order signals from either a local or remote control station, accurately position the gun. As in the case of the 5"/38 power drive system, the train and elevation drives are basically similar, so only the elevation drive will be covered here.

GENERAL DESCRIPTION

The elevation power drive consists of a 40-horsepower electric motor, a gear reduction unit, a hydraulic transmission (A-end and B-end), a receiver-regulator, and a mechanical gear assembly. The electric motor, through the gear reduction unit, drives the A-end of the hydraulic transmission at a constant speed. The A-end, in turn, drives the B-end and, consequently, the elevation gearing at a speed and in a direction determined by the receiver-regulator. At its opposite end, the electric motor drives an auxiliary gear pump. Figure 5-20 shows you the layout of the principal components of the elevation power drive system.

Electric Motor and Gear Reducer

The elevation gear electric motor and gear reducer assembly provide a constant speed power input to the hydraulic transmission. The motor is a 440-volt squirrel cage induction motor rated at 40 horsepower. The drive shaft out the front of the motor is attached to the driver gear of the gear reducer. To the rear of the motor, the drive shaft drives the auxiliary gear pump, which furnishes both control and replenishing pressures to the hydraulic system.

The gear reducer (fig. 5-21) consists of two helical gears, a driver pinion on the motor shaft and a driven gear integral with an output shaft to the A-end pump. The ratio of shaft reduction through the gear reducer is 1.3793 to 1.

HYDRAULIC TRANSMISSION

The hydraulic transmission (fig. 5-22) is a variable-displacement hydraulic pump (A-end) and a constant-displacement hydraulic motor (B-end) that transmits power to drive the elevating gear. The transmission, mounted on the base ring to the rear of the elevating pinion and worm drive, is stroke controlled by hydraulic pressures from the receiver-regulator. The major components of the transmission include an A-end, a B-end, a main relief valve, an auxiliary gear pump, an auxiliary relief valve block, and response gearing. Control components of the drive system, such as the receiver-regulator and its valve block, will be discussed in chapter 6 of this course.

A-End

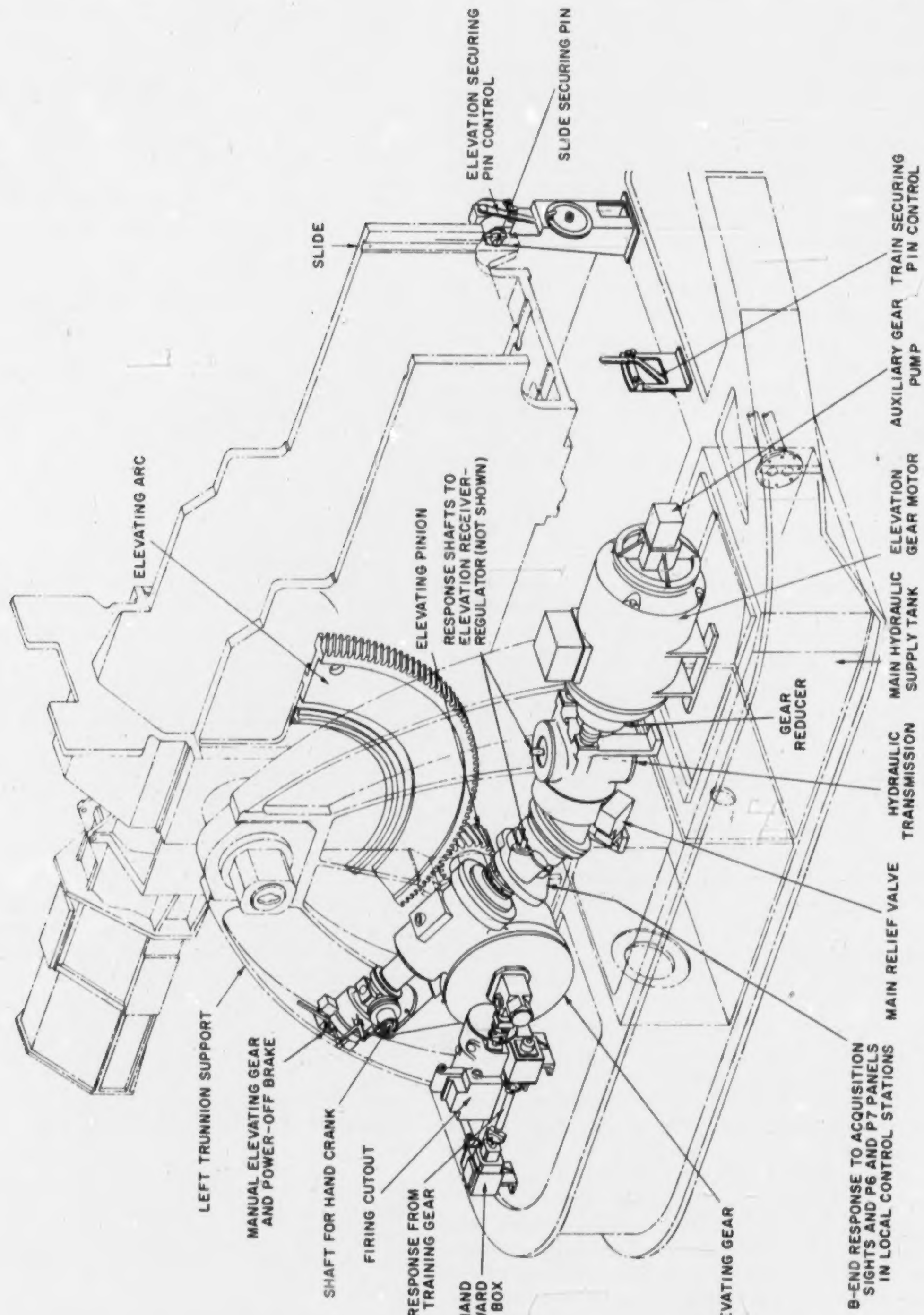
The A-end is a nine-cylinder axial piston variable displacement pump driven by the electric motor gear reducer. It consists of a housing, a rotating group, and a tilting plate mechanism.

The housing consists of a case and a valve plate. The case is essentially a cylinder, flanged at the front end for bolting to the valve plate and expanded laterally, at the mid-section and rear, to clear the tilting plate mechanism. Covers retain the tilting plate bearings. Openings in the rear wall support a drive shaft bearing retainer and hydraulic cylinders for control pistons.

The valve plate completes the A-end housing and serves as a bolting plate between the A-end and the B-end housings. A central hole in the plate supports the forward bearing of the A-end drive shaft. Openings through the plate, arranged in circles around its face, hydraulically connect the A-end with the B-end. The plate, also, supports the main relief valve on its inboard side. Passages within the plate connect the valve with both the A-end and the B-end.

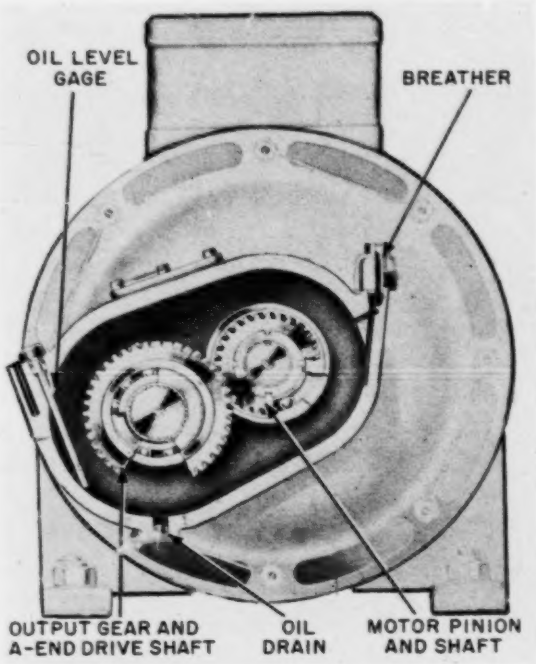
The rotating group consists of a drive shaft, a socket ring and pistons, and a cylinder barrel. The drive shaft supports and drives the cylinder barrel and drives the socket ring, which is connected with the shaft through a universal joint.

The socket ring, a circular plate, retains the ends of connecting rods attached to the A-end pistons. The ring rotates in the tilting


ELEVATION SECURING PIN CONTROL
SLIDE SECURING PIN
SLIDE
TRAIN SECURING PIN CONTROL
AUXILIARY GEAR PUMP
ELEVATION GEAR MOTOR
MAIN HYDRAULIC SUPPLY TANK
ELEVATING ARC
ELEVATING PINION
RESPONSE SHAFTS TO ELEVATION RECEIVER-REGULATOR (NOT SHOWN)
GEAR REDUCER
HYDRAULIC TRANSMISSION
MAIN RELIEF VALVE
B-END RESPONSE TO ACQUISITION SIGHTS AND P6 AND P7 PANELS IN LOCAL CONTROL STATIONS
LEFT TRUNNION SUPPORT
MANUAL ELEVATING GEAR AND POWER-OFF BRAKE
SHAFT FOR HAND CRANK
FIRING CUTOUT
RESPONSE FROM TRAINING GEAR
LEFT HAND FORWARD GEAR BOX
ELEVATING GEAR

53.212

Figure 5-20.—Elevation Power Drive (Type "C" Installation).



53.213
Figure 5-21.— Elevation Drive Gear Reducer.

plate. The plane, or angle of tilt, of this rotation of the socket ring governs the output of the A-end.

The tilting plate mechanism controls the output of the A-end in accordance with hydraulic pressures from the receiver-regulator. The mechanism consists of a tilting plate and two stroking pistons and cylinders. The tilting plate supports the socket ring bearings. This plate is between ball bearings in the top and bottom of the housing so that the plate can move on a vertical axis. Two bosses, one on the inboard and one on the outboard side of the tilting plate, are each attached, on the rear side, to a stroking piston. These pistons are retained in cylinders attached to the rear of the housing. Hydraulic pressures applied to these stroking piston cylinders move the pistons to control the position of the tilting plate and socket ring on the vertical axis. A response shaft that registers the position of the tilting plate in the receiver-regulator is attached to the top of the tilting plate.

B-End

The B-end is a nine-cylinder axial piston constant displacement hydraulic motor that drives the elevating gear. This motor, which composes the forward portion of the transmission, is driven by hydraulic pressures from the A-end. The B-end consists of a housing and rotating components.

The housing is bolted to the forward side of the valve plate and is essentially a cylindrical, flanged, steel housing that encloses a cylinder barrel and supports the B-end angle plate. This plate is bolted to the forward end of the cylinder barrel housing and is at a fixed angle of 30 degrees with the axis of the cylinder barrel.

The rotating group consists of the cylinder barrel, the drive shaft and motor pistons, and a drive link. The cylinder barrel rotates on a bearing supported by a stub shaft projecting from the front of the valve plate. A central opening in the barrel retains a key block and, also, a spring that holds the barrel against the valve plate.

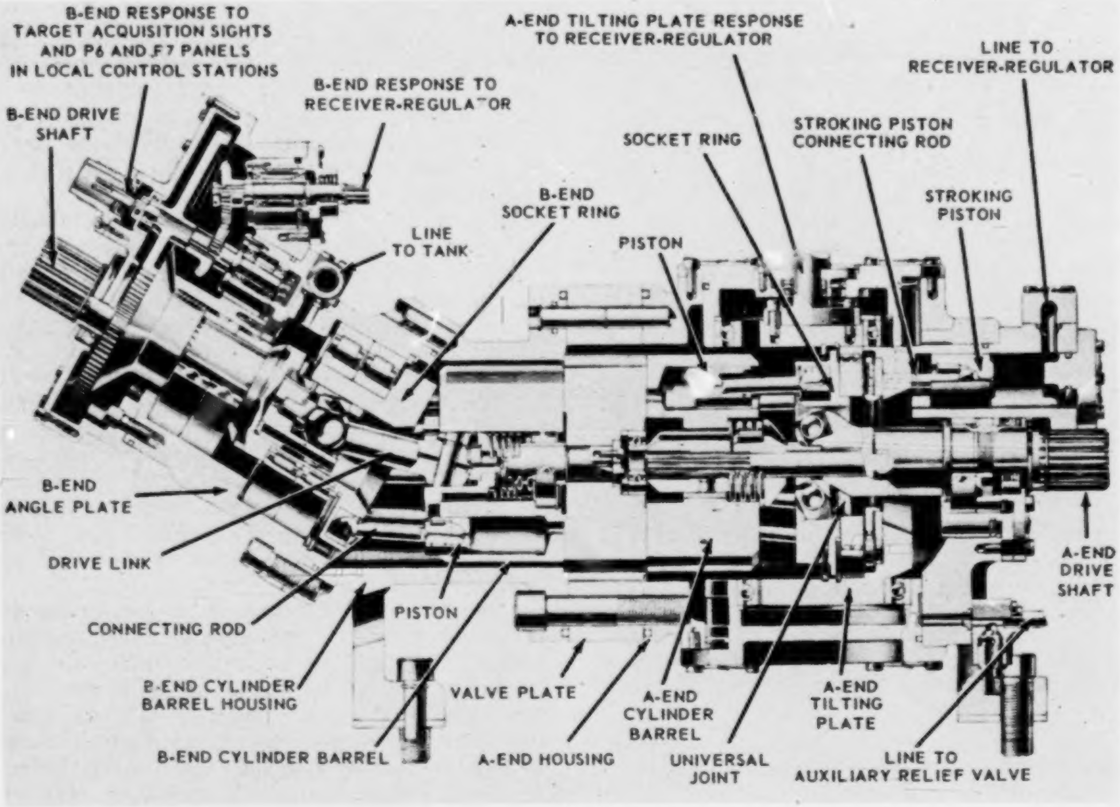
The pistons are attached by connecting rods to the rear face of the drive shaft—a combined socket ring and power output shaft. The shaft is supported in the angle plate on two roller bearings at the rear and two ball bearings at the front. The rear end of the shaft is flanged to form the socket ring and expanded and centrally recessed for a key block and the drive link. At this other end, the drive shaft is coupled to the elevating gear and, also, drives a response spur gear.

The drive line, a shaft with cross pins and keys at each end, maintains a constant rotational relationship between the cylinder barrel and the drive shaft. The ends of the link are seated within the key blocks recessed in the cylinder barrel and drive shaft.

To identify and better understand the components of the A-end and B-end just described, study figure 5-22.

Main Relief Valve

The main relief valve is a combined pressure bypass and replenishing valve that relieves excessive pressures in the transmission, and admits fluid to the A-end and B-end pistons to replace circulating fluid lost by leakage. The relief valve is located on the outboard side of the transmission, bolted to the transmission valve plate (fig. 5-23). It is connected hydraulically by internal passages in the valve plate to the


B-END RESPONSE TO TARGET ACQUISITION SIGHTS AND P6 AND F7 PANELS IN LOCAL CONTROL STATIONS
B-END DRIVE SHAFT
B-END RESPONSE TO RECEIVER-REGULATOR
LINE TO TANK
B-END SOCKET RING
A-END TILTING PLATE RESPONSE TO RECEIVER-REGULATOR
SOCKET RING
PISTON
STROKING PISTON CONNECTING ROD
LINE TO RECEIVER-REGULATOR
STROKING PISTON
B-END ANGLE PLATE
DRIVE LINK
CONNECTING ROD
PISTON
B-END CYLINDER BARREL HOUSING
B-END CYLINDER BARREL
VALVE PLATE
A-END HOUSING
A-END CYLINDER BARREL
UNIVERSAL JOINT
A-END TILTING PLATE
LINE TO AUXILIARY RELIEF VALVE
A-END DRIVE SHAFT

53.214
Figure 5-22. — Elevation Power Drive Hydraulic Transmission.

pressure and exhaust lines between the A-end and B-end, and by two external lines to the auxiliary relief valve block.

The main relief valve is of the Northern Duplex type and has the following three functions:

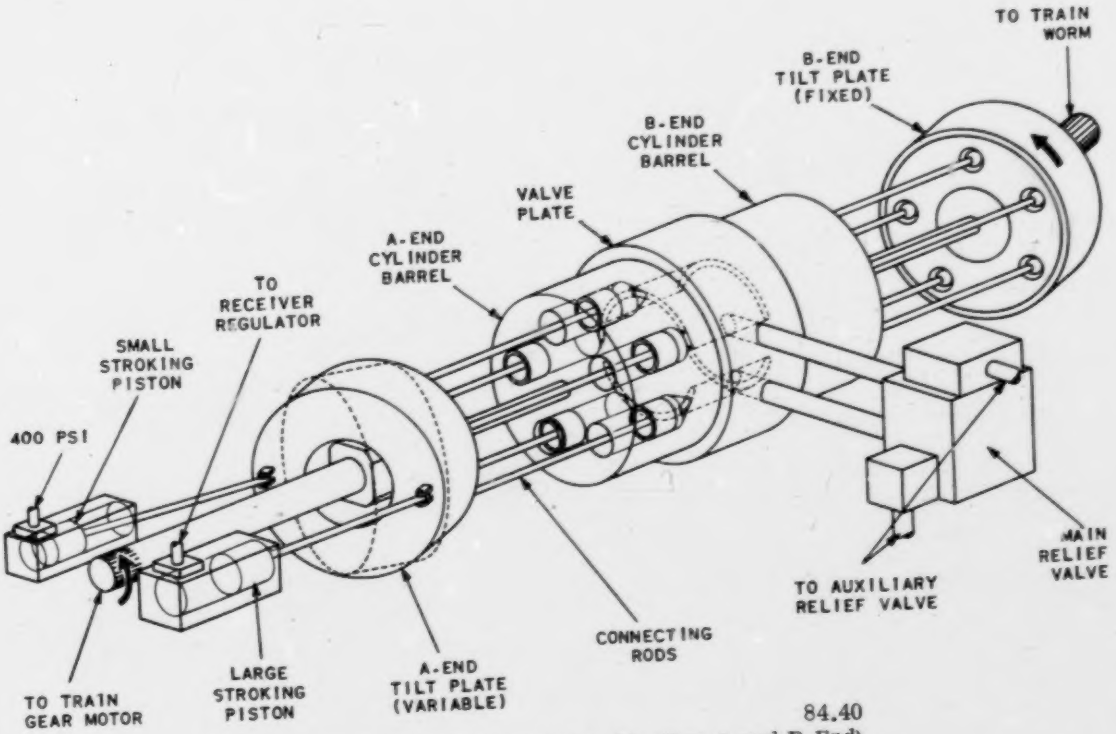
1. It limits the pressure in the lines between the A-end and B-end.
2. It serves as a bypass valve when the B-end brake is set (Manual elevating gear and power-off brake).
3. It furnishes supercharge oil and replenishes slippage oil in the lines between the A-end and the B-end.

The valve assembly consists of a taper-seated main plunger, a pilot or regulating valve built into the center of the main plunger, two small directional ball check valves built into the tapered end of the main plunger, and two large supercharge ball check valves. When the main plunger is seated, the high and low pressure sides are blocked off from each other. When the plunger is unseated, the high pressure side of the valve plate vents to the low pressure side.

Operation of Main Relief Valve

In order to see the operation of the main relief valve more clearly, the valve assembly is shown in schematic form in Figure 5-24.

The large taper-ended main plunger is controlled by the action of the small pilot plunger. The bottom of the main plunger is divided, by the seating in the block, into two equal areas (area A and area B), each area equal


TO TRAIN WORM
B-END TILT PLATE (FIXED)
B-END CYLINDER BARREL
VALVE PLATE
A-END CYLINDER BARREL
TO RECEIVER REGULATOR
SMALL STROKING PISTON
400 PSI
MAIN RELIEF VALVE
TO AUXILIARY RELIEF VALVE
CONNECTING RODS
A-END TILT PLATE (VARIABLE)
LARGE STROKING PISTON
TO TRAIN GEAR MOTOR

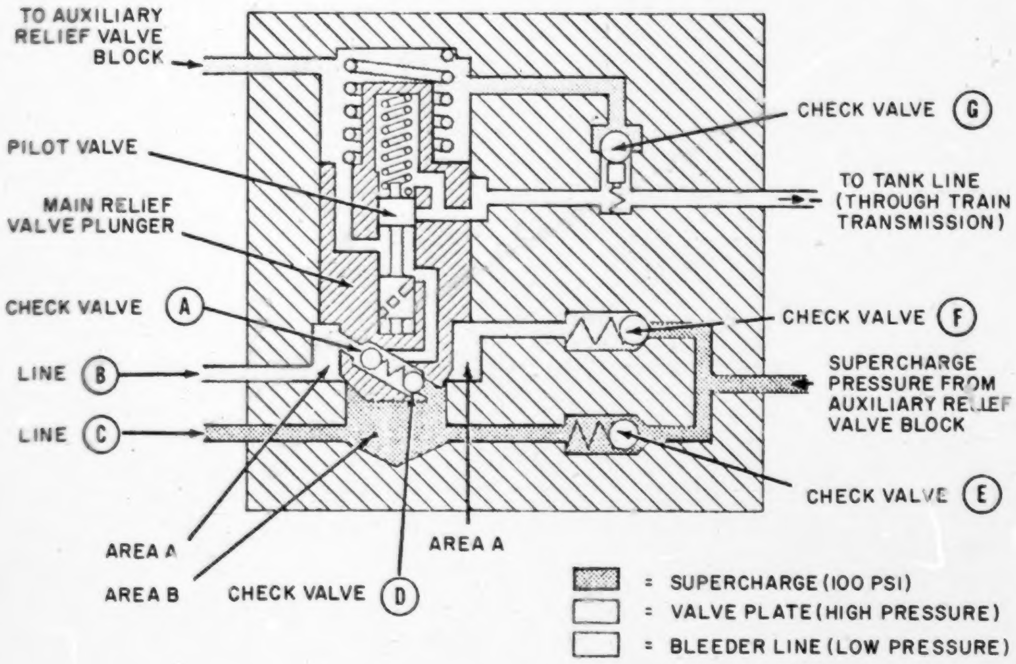
84.40
Figure 5-23.—Cab Unit (Combination A and B End).

to one-half of the area at the top of the plunger. Each area is connected to one of the valve plate ports and, through check valves E and F, to supercharge-replenishing pressure. When the transmission is at zero stroke, both main lines (B and C) are maintained at the supercharge-replenishing pressure of 100 pounds per square inch from the auxiliary relief valve block.

As soon as the A-end is stroked, the pressure in one line will rise (schematic shows line B pressure increased). The higher pressure will close check valve F and open check valve A, allowing the fluid to flow through a passage to the pilot valve chamber. From there, the fluid flows through the pilot valve and through another passage to the top of the main plunger. The other line from the top of the main plunger leads to the auxiliary relief valve block and is vented to tank or 400 pounds per square inch pressure by the auxiliary relief valve action. Under normal operating conditions, however, 400 pounds per square inch is applied to the top of the plunger. At transmission differential pressures of 400 pounds per square inch or below, the pressure is maintained at 400 pounds per square inch by this auxiliary relief valve action. At pressures above 400 pounds per square inch, the pressure is limited by the pilot valve action.

Since the area on top of the main relief valve plunger is twice that of area A at the bottom, it will require only one-half of the relief valve setting to hold the main plunger closed. This is the purpose and action of the pilot valve. If, for example, the relief valve is set to relieve and bypass at 2000 pounds per square inch, the pressure applied to the top of the plunger will be regulated to 1000 pounds per square inch by the pilot valve whenever the line pressure applied to area A reaches or exceeds 1000 pounds per square inch.

The high pressure fluid enters the land chamber, between the two pilot valve lands, and down through a passage in the lower land to the bottom of the pilot valve chamber, where it acts in opposition to the adjusted spring


TO AUXILIARY RELIEF VALVE BLOCK
PILOT VALVE
MAIN RELIEF VALVE PLUNGER
CHECK VALVE (A)
LINE (B)
LINE (C)
AREA A
AREA B
CHECK VALVE (D)
AREA A
CHECK VALVE (G)
TO TANK LINE (THROUGH TRAIN TRANSMISSION)
CHECK VALVE (F)
SUPERCHARGE PRESSURE FROM AUXILIARY RELIEF VALVE BLOCK
CHECK VALVE (E)
▨ = SUPERCHARGE (100 PSI)
☐ = VALVE PLATE (HIGH PRESSURE)
☐ = BLEEDER LINE (LOW PRESSURE)

53.271

Figure 5-24.—Schematic Diagram of Main Relief Valve.

tending to keep the valve down. As the pressure in area A reaches 1000 pounds per square inch, the pilot valve moves up, closing off the inlet pressure to the top of the main plunger, and allows excess pressure to escape through the upper land which is vented to tank through the transmission housing.

When the pressure on the top of the main plunger drops below 1000 pounds per square inch, the spring forces the pilot valve down and high pressure fluid is again allowed to enter. By this valve action, a constant pressure of 1000 pounds per square inch is maintained on the top of the main plunger whenever the pressure in the high pressure line is 1000 pounds per square inch or more. Then, whenever the force on Area A (area times applied pressure) exceeds the force on the top of the main plunger, the main plunger is forced up, allowing the high pressure to relieve to the low pressure side until the high pressure side drops to below the relief valve setting where the main plunger will again close.

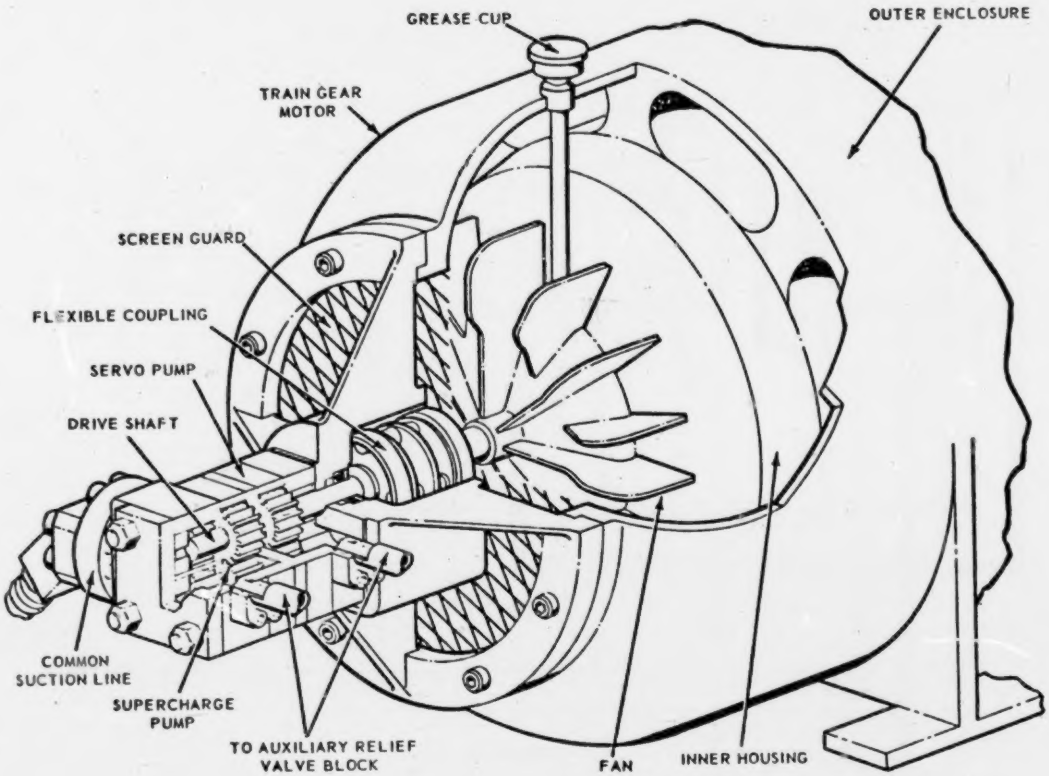
When line C or area B is the high pressure side, the high pressure fluid keeps check valve E closed but opens the other check valve D to admit high pressure to the pilot valve chamber. Check valve F would also open to admit supercharge-replenishing oil. Other valve action is exactly the same as previously explained.

Check valve G is used to relieve the pressure build ups in the valve resulting from pumping action during manual hand crank operation. During normal operation the high pressures seat the check valve as shown in figure 5-24, sealing off the upper valve chamber except for the relieving through pilot valve action.

ADJUSTMENT OF RELIEVING PRESSURE.—The pressure at which the relief valve actuates and relieves the high pressure to the low pressure side is controlled by the adjustment of the pilot valve spring force. Any adjustment is made by the addition to or subtraction from the fixed spring spacer under the plunger guide seal.

Auxiliary Gear Pump

The auxiliary pump, mounted on the rear of the elevation electric motor (fig. 5-25) is a



53.272
Figure 5-25.— Auxiliary Gear Pump.

two-section gear pump assembly driven through a flexible coupling by the electric motor. The front section is the servo pump; the rear, the supercharge pump. Each draws hydraulic fluid from the main supply tank of the upper hoist and gun loading hydraulic system through a common intake line, and discharges it through separate pressure lines.

The servo pump supplies servo pressure fluid, through a check valve, to the auxiliary relief valve block. In the valve block it is regulated to two pressures: a servo pressure at 400 psi, and a control pressure at 200 psi.

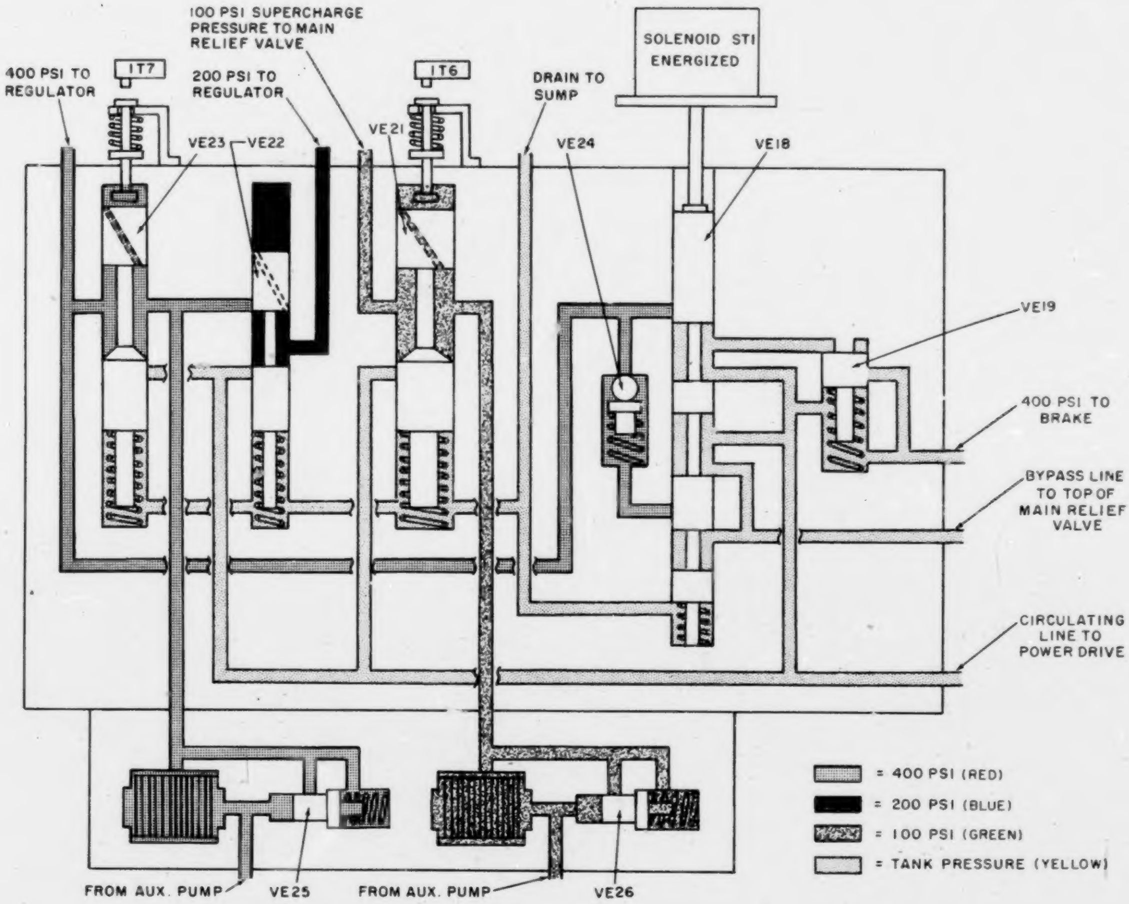
The supercharge pump supplies supercharge pressure fluid, through a check valve in the pressure line, to a regulator valve in the auxiliary relief valve block where it is regulated to 100 psi. After regulation, the fluid is applied to the circulating system of the hydraulic transmission to replenish fluid lost through leakage.

Auxiliary Relief Valve Block

The auxiliary relief valve block controls and regulates operating pressures for the power-off brake, the main relief valve, and the receiver-regulator. Mounted on the base ring inboard of the electric motor gear reducer, the assembly is connected through piping to the auxiliary gear pump and the units that are served. A filter block is attached to the rear of the relief valve assembly.

The valve block, mounted by means of a bracket, is bored for the valves, and for inlet, interconnecting, and outlet passages (fig. 5-26).

Two of the valves (VE22 and VE23) furnish the receiver-regulator with servo control pressures at 400 and 200 psi. A third valve (VE21) regulates the transmission supercharge supply. The three remaining valves (VE18, VE19, and VE24) operate in conjunction with one another to either bypass or set the B-end brake and


100 PSI SUPERCHARGE PRESSURE TO MAIN RELIEF VALVE
SOLENOID STI ENERGIZED
400 PSI TO REGULATOR
IT7
200 PSI TO REGULATOR
IT6
DRAIN TO SUMP
VE23
VE22
VE21
VE24
VE18
VE19
400 PSI TO BRAKE
BYPASS LINE TO TOP OF MAIN RELIEF VALVE
CIRCULATING LINE TO POWER DRIVE
= 400 PSI (RED)
= 200 PSI (BLUE)
= 100 PSI (GREEN)
= TANK PRESSURE (YELLOW)
FROM AUX. PUMP
VE25
FROM AUX. PUMP
VE26

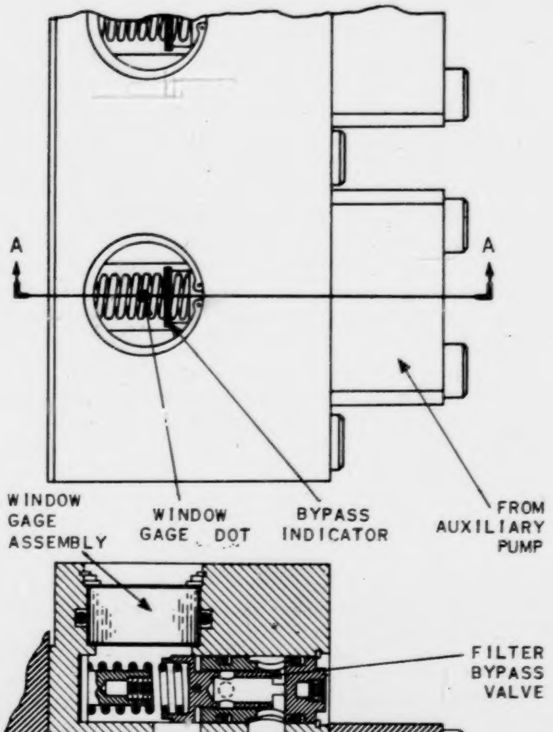
53.215
Figure 5-26.— Auxiliary Relief Valve Block in Power-off Condition.

the main relief valve at the proper time and in the proper sequence.

Two filters, one in each of the hydraulic lines from the auxiliary pump, are mounted in a block attached to the rear of the auxiliary relief valve block. Each has a single filter cartridge enclosed in an individual bowl threaded into the bottom of the filter block for easy removal. A spring-loaded bypass valve, arranged between the inlet and outlet ports of each filter, permits the fluid to bypass the filter cartridge should excessive clogging of the cartridge create a pressure differential of 50 psi or over between the inlet and outlet ports. These bypass valves are designated VE25 and VE26 (fig. 5-26). A white washer on the valve plunger, which can be seen through a sight glass in the block above each of these two valves, provides an indication of filter condition (fig. 5-27). When the washer on the plunger coincides with a white dot in the center of the glass while the pumps are operating, the filter is clogged and the cartridge should be replaced.

Response Gearing

The response gearing is a train of gears that transmits the angular displacement of the B-end drive shaft to a response shaft connected to the elevation receiver-regulator. The gearing, enclosed in the housing secured to the front end of the B-end angle plate, consists of a straight



53.216
Figure 5-27.—Filter Assembly.

spur gear attached to the B-end drive shaft, a straight spur gear and bevel gear supported on a pinion shaft, and a bevel gear supported on an output shaft. The output shaft is supported in a horizontal plane at an angle of 30 degrees with the B-end drive shaft. Another response takeoff on the forward side of the B-end response gearing housing drives a flexible cable that transmits B-end response to the target acquisition sights and the P6 and P7 panels in the left and right local control stations. In chapter 6 of this course, information on how all this is used in controlling the elevation drive is given.

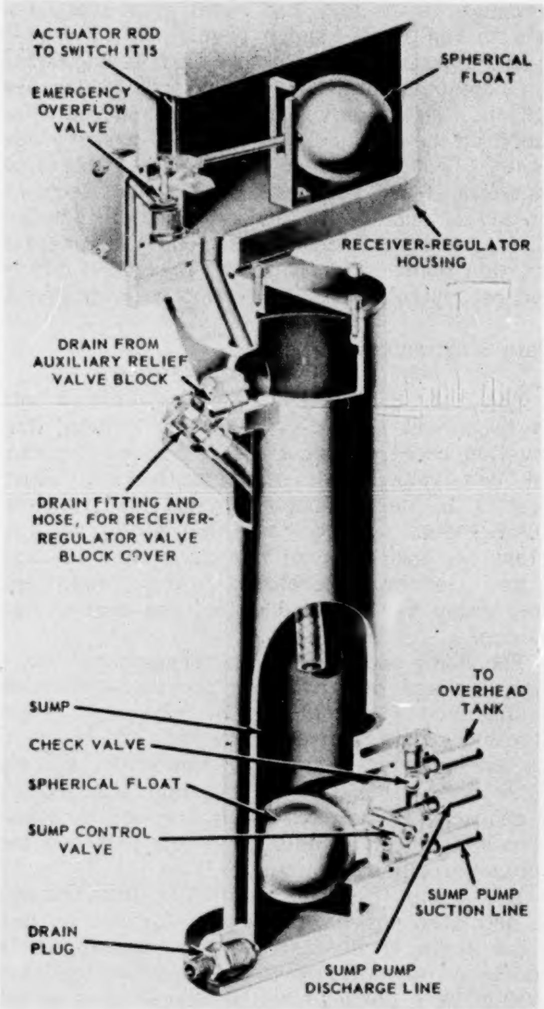
Train Sump and Sump Pump

The main hydraulic supply tank serves both the train and elevation hydraulic system. The elevation receiver-regulator sits above the main tank and leakage from its valve block is piped down to the tank through gravity. The train receiver-regulator, however, is situated at too low a level to take care of its valve block leakage in this manner. Therefore, a train sump and sump pump has been added to take care of this problem.

The sump and sump pump arrangement evacuates leakage oil from the receiver-regulator housing and from the train auxiliary relief valve block, and returns it to the hydraulic system. The arrangement consists of the sump, a sump control valve, and a sump pump and motor. In addition, it includes an emergency overflow valve and switch actuator that are parts of the receiver-regulator housing.

The sump (fig. 5-28) collects this leakage oil and also serves as support for one corner of the train receiver-regulator housing. It is connected hydraulically at the top to the regulator housing by a passage in the bracket and to the train auxiliary relief valve block by a pipe adapter and line. At the bottom of the sump, a cylindrical extension of the weldment houses the sump control valve, while the base of the sump contains a drain plug. A screw-covered opening in the upper part of the sump provides a convenient storage place for a short length of hose used to drain the front cover of the receiver-regulator valve block.

The sump pump (fig. 5-29) is a constant displacement gear type pump that pumps oil from the sump and discharges it into the overhead tank. (The overhead tank is a small tank that maintains a gravity head of fluid in the tank lines from the valves in the receiver-regulator to prevent entrance of air into the hydraulic


ACTUATOR ROD TO SWITCH IT15
EMERGENCY OVERFLOW VALVE
SPHERICAL FLOAT
RECEIVER-REGULATOR HOUSING
DRAIN FROM AUXILIARY RELIEF VALVE BLOCK
DRAIN FITTING AND HOSE, FOR RECEIVER-REGULATOR VALVE BLOCK COVER
TO OVERHEAD TANK
SUMP
CHECK VALVE
SPHERICAL FLOAT
SUMP CONTROL VALVE
SUMP PUMP SUCTION LINE
DRAIN PLUG
SUMP PUMP DISCHARGE LINE

53.217
Figure 5-28.—Train Sump Assembly.

system.) The pump is driven by a one-sixth horsepower, 440-volt induction motor. The pump suction line is connected to the bottom of the sump control valve (fig. 5-28). The discharge line is also connected through the sump control valve.

The sump control valve has the important role of ensuring a steady flow of oil through the pump. If there is not enough oil in the sump to provide an oil flow through the pump, the sump pump will soon fail due to lack of lubrication. A spherical float near the bottom of the sump opens and closes the sump control valve. When the oil level in the sump is high enough, the float will rise and close off the sump control valve. When this happens, pressure will force open the check valve between the pump discharge line and the line to the overhead tank, and the excess oil from the sump is pumped to the overhead tank. When the oil level drops enough, the float drops also and the sump control valve opens. The remaining oil in the sump then merely keeps recirculating through the pump to keep it lubricated.

In the event that the sump pump should fail, an emergency overflow valve in the receiver-regulator housing will prevent oil from rising up into the housing. When oil from the sump begins to rise into the regulator housing, a spherical float there will lift and open the emergency overflow valve (fig. 5-28). The oil will then drain out on deck. An actuator rod attached to an electrical switch will light a warning at the mount captain's panel, informing him of the pump's failure.

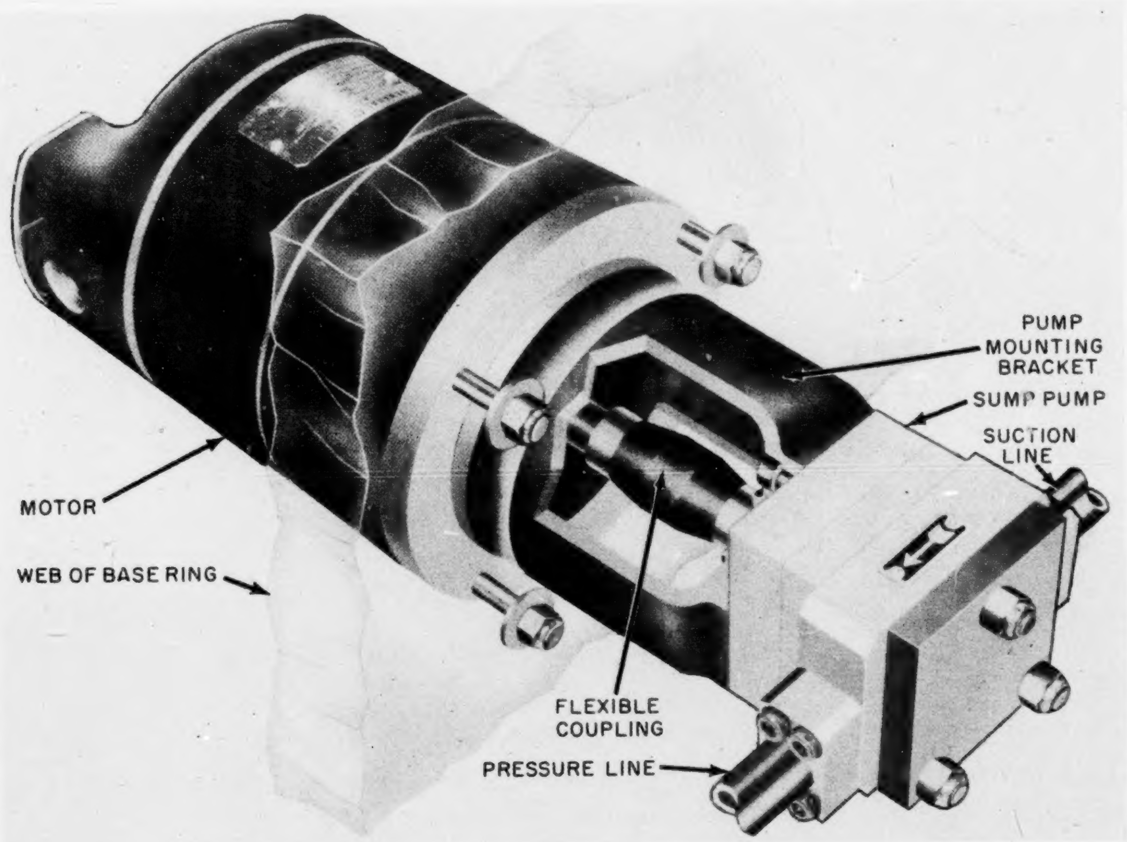
CONTROL

The mount's power drive may be operated by either remote or local control. It is normally operated in remote control. In this type of control, gun orders from a director are corrected at a fire control computer and transmitted to the receiver-regulators in the mount. In local control, gun orders can be applied to the receiver-regulators (train and elevation) by either of the one-man control (OMC) units in the mount local control stations. Local control is used during starting, purging, and stowing operations, for exercising and standby purposes, and for emergency mount control when remote control gun orders are not available.

Chapter 6 of this course, on control equipment, will give you more detailed information on both types of control of the 5''/54 power drive.

MANUAL ELEVATING GEAR AND POWER-OFF BRAKE

The manual elevating gear and power-off brake is a hydraulically and manually released, spring-loaded, friction clutch and a handcrank input gear housed as a unit. The assembly, mounted on the forward end of the elevating gear housing



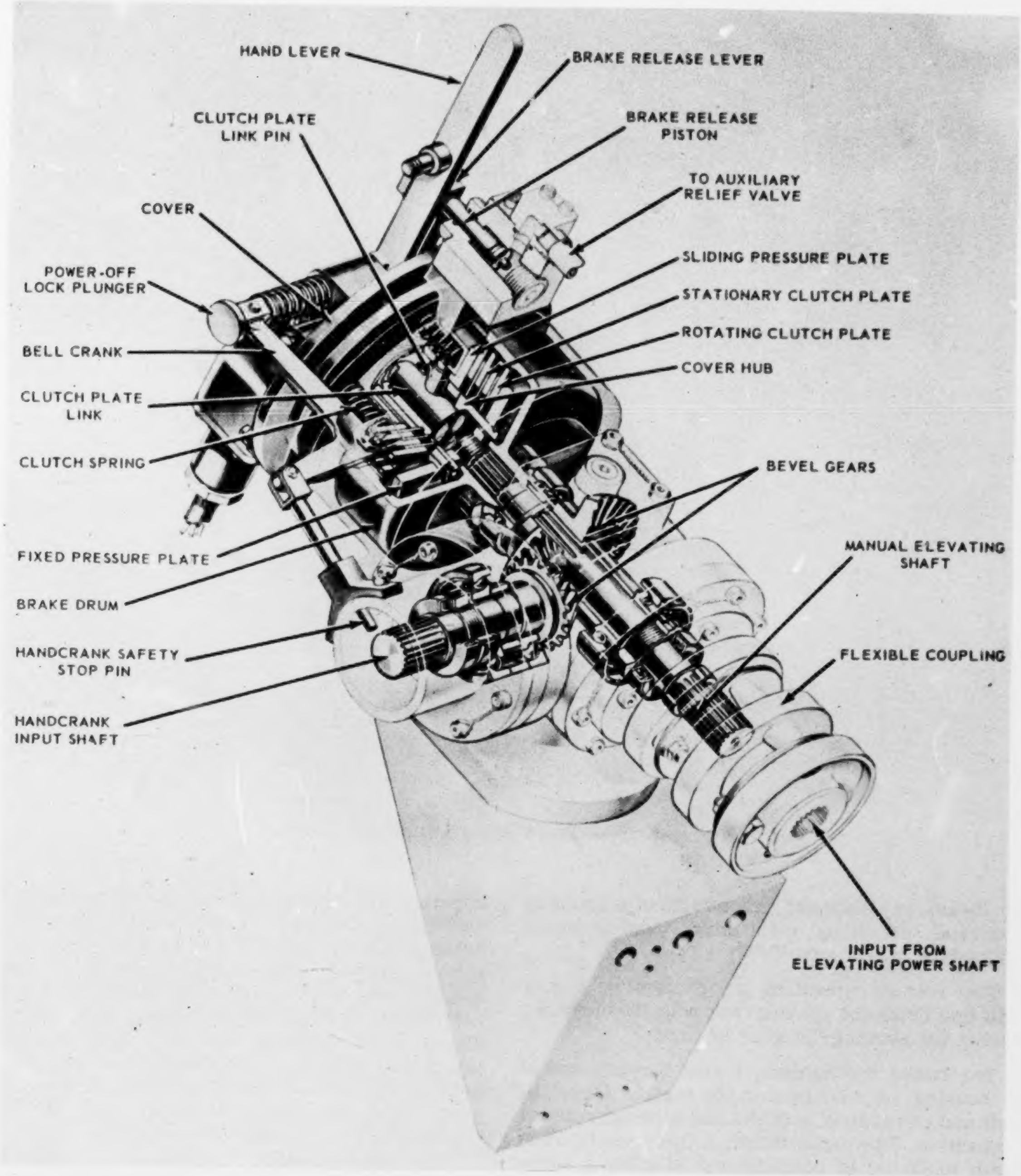
53.218
Figure 5-29.—Train Sump Pump and Motor.

(fig. 5-20), is composed essentially of a housing, a manual elevating mechanism, and a brake mechanism. (See figure 5-30)

The manual elevating mechanism is a gear train that connects a handcrank with the elevating gearing for stowing the gear by hand.

The brake mechanism, in the forward end of the housing, is connected to the manual elevating shaft and consists of a brake and a brake release mechanism. The brake is a multiple-disc friction clutch made up of rotating and stationary components. The rotating group consists of a brake drum and four rotating clutch plates. The stationary group consists of three nonrotating clutch plates, a fixed and a sliding pressure plate mounted on the hub of the brake cover, a spring housing, and eight compression coil springs. The stationary clutch plates are retained between the rotating clutch plates. They are keyed to the hub to prevent rotation. The spring housing is a steel ring with cylindrical recesses that seat the clutch springs. The housing encircles the sleeve of the sliding pressure plate and bears against the flange. The springs maintain pressure between the clutch plates to keep the brake engaged until the sliding pressure plate is moved forward by the release-link cross pin.

The brake release mechanism is made up of two release systems; a hydraulic release for power operation of the elevating gear, and a hand release for manual operation. The hydraulic release consists of a release lever, a linkage and cross pin that connect the lever with the


HAND LEVER
BRAKE RELEASE LEVER
CLUTCH PLATE LINK PIN
BRAKE RELEASE PISTON
TO AUXILIARY RELIEF VALVE
COVER
SLIDING PRESSURE PLATE
POWER-OFF LOCK PLUNGER
STATIONARY CLUTCH PLATE
ROTATING CLUTCH PLATE
BELL CRANK
COVER HUB
CLUTCH PLATE LINK
CLUTCH SPRING
BEVEL GEARS
MANUAL ELEVATING SHAFT
FIXED PRESSURE PLATE
BRAKE DRUM
HANDCRANK SAFETY STOP PIN
FLEXIBLE COUPLING
HANDCRANK INPUT SHAFT
INPUT FROM ELEVATING POWER SHAFT

53.219
Figure 5-30. — Manual Elevating Gear and Power-off Brake.

sliding pressure plate of the brake, and a hydraulic piston. The hydraulic piston is enclosed in a cylinder block attached to the top of the brake housing. Hydraulic pressure, ported from the auxiliary relief valve block, applied to the piston causes the piston to move the upper end of the lever forward to release the brake for power operation of the elevating gear. Should power be lost, oil pressure to the brake release piston will also be lost, and spring pressure will re-set the power-off brake.

For manual operation of the elevating gear, the brake may be released manually by a hand lever (fig. 5-30). An interlock system prevents power actuation of the elevation system until the hand release lever has been reset.

SIMILARITY OF SYSTEMS

The two power drive systems presented in this chapter as typical examples were both designed for the same purpose—to position a gun mount quickly and accurately. While component design features may differ considerably from system to system, a close study will, in many cases, show that although they may appear quite different, they have been designed to perform like functions in their systems. Some components may be so similar that the chief difference is only a matter of nomenclature. Let's review a few examples of these similarities.

In the 5''/38 drive just described, the brake valves returned the A-end tilting box to neutral and stopped mount motion whenever control pressure was lost in the system. In the 5''/54 drive, we learned that the power-off brake gave us this same end result, only in a different manner. In the one system, the electric power motor drove an auxiliary pump cluster at its rear. In the other, it similarly drove an auxiliary gear pump, the assemblies performing very similar functions in their systems. The A-end tilting box of the 5''/38 was positioned by the main cylinder and piston to control A-end output, while in the 5''/54, this was done by two stroking pistons positioning a tilting plate and socket ring. Control and replenishing oil pressures were regulated by independent relief valves in the 5''/38 drive. In the 5''54 drive, these pressures were regulated in the auxiliary relief valve block. Both systems utilized a sump pump, although it was necessary for the train drive only in the 5''54 system. The 5''/38 sump pump also included an oscillator in its makeup which helped to eliminate static friction in the hydraulic valves. This pulsating effect, sometimes called dither, is transmitted to the valves in the 5''/54 system in quite a different way, but gives the same result. A 60-cycle a-c current is introduced to the grid of one of the tubes in the servoamplifier which results in a very slight, but rapid, vibration being imparted to the various valves in the system. (You will learn about the servoamplifier in chapter 6 of this course.)

So you see, one hydraulic drive system is, basically, not so very different from another. Once you have become familiar with one type, it should not be difficult to learn another.

MAINTENANCE

Hydraulic power drives are rugged, proven machines. Properly inspected and installed, they will operate for an indefinite period of time. Strict adherence to the instructions in the maintenance publications will help the equipment to retain its design characteristics of power, speed, and control, and eliminate extensive repairs and costly replacement.

Hydraulic systems which perform satisfactorily and show no evidence of sludge, rust, or malfunctions should not be opened. All cover nuts should be kept tightly secured to discourage removal without good reason.

The statements above do not mean that casualties won't occur in your equipment, but rather that when they do happen you should reach first for your OP, not a wrench. Correct casualty analysis can be made only by someone with a thorough knowledge of the operation of the equipment.

Many hydraulic power drives have seen years of service. Due to constant use, working parts may become worn and springs will become weakened. Hydraulic transmission oil will become contaminated with moisture and foreign material. Vibrations, over a period of time, cause copper tubing to crystallize and crack. This condition is especially prevalent in smaller tubing near flanges.

To combat these troubles, and to prevent malfunctions from developing to a stage where they will seriously affect mount operation, a routine maintenance program, including daily checkoffs, is essential.

FLUID LEVEL AND PRESSURE CHECKS

Frequent checks should be made to assure proper fluid level in the system. Impress on the men working for you, especially the strikers, the hazards of neglecting the hard-to-get-to spots. An example of such a place is the dip stick on the 5''/38 twin mount elevation main reduction gears. The removal of a plate for access to the dip stick takes much less time than removing this heavy assembly for repairs.

The various pressures present in a hydraulic power drive—pump high pressure, response pressure, and low pressure—must be maintained at their specified levels for proper mount operation. The OPs state these pressures, giving the correct value in psi for each.

In the event of a casualty you may be required to take readings of these pressures to make a comparison with the correct value as listed in the OP.

Gauges are furnished you for this purpose. Connection plugs for inserting the gauge into the suspected system may be found at filters, pump outlets, and valve blocks.

PUMPS

As a rule pumps in hydraulic power drive systems require little maintenance other than proper lubrication and a clean hydraulic system to operate in. In addition to the obvious failure of a pump to deliver its designed output because of worn or broken parts, other signs of trouble are unusual noise and overheating. Many times the cause of these two symptoms will not be in the pump itself. A frequent cause of noise is the failure of oil to reach the pump. This condition can be caused by low oil level in the reservoir, or by clogged lines or filters. Since the pump depends upon liquid for lubrication, failure of the oil supply will soon cause the pump to heat up, and probably cause its parts to bind.

Another cause of abnormal noise is poor alignment between a pump and its driving mechanism. This condition will cause worn parts and possibly leakage, reducing the pump's efficiency.

Pounding or rattling noises in axial piston pumps may be unavoidable due to a partial vacuum produced in the active system during high speed operation or under heavy loads. It should, however, stop when the load is reduced. If not, you will have to bleed air from the system.

Use special care when you reassemble a rotary gear type pump. The rotors operate in a pump easing or body. End plates enclose the rotors on each side. When tightening the screws holding the sections together, use only moderate force. Make them just tight enough to allow free movement of the rotor with no leakage.

Hydraulic systems which perform satisfactorily, and which show no evidence of sludge, rust, etc., should not be opened. Cover plates should be kept tightly secured, and you should discourage their removal without good reason.

HYDRAULIC OIL

The fluids specified for use in hydraulic power drives are currently of the petroleum-base type, containing additives to improve certain of their chemical and physical properties.

These fluids must be chemically stable and nonfoaming. They must have a high viscosity index, adequate lubricating qualities, and a low pour point. They must have no harmful effects on, and not be affected by, the metal parts of the system.

Fluid MIL-F-17111 (N Ord), formerly 51-F-21, is the power transmission fluid generally approved for hydraulic power drives. While its lubricating properties make it adequate as a lubricant within hydraulic transmission systems, it is not a general purpose lubricating oil. It should never be used on any parts or other mechanisms for which other lubricants are prescribed.

Certain individual power drive components, such as reduction gears and gear brackets, require fluids with different characteristics. This is because they operate under different loads, speeds, etc. OD 3000 and lubrication charts indicate the approved fluid, frequency of application, and approved substitutes. They also contain additional information relating to draining, filling, and other maintenance functions in conjunction with lubrication.

Setting standards for hydraulic fluids, and outlined their proper service applications, is the responsibility of NAVORD. It is your responsibility, however, to maintain the condition of the oil when it is placed in your equipment.

A hydraulic system must be substantially free of contaminants such as water, dirt, insoluble products resulting from oxidization, corrosion products, and metal particles. These contaminants may cause damage to working surfaces, sticking of operating components, or clogging of filters, resulting in erratic performance or complete failure of the equipment.

FILTERS

Filters used in hydraulic systems serve mainly to remove insoluble particles from the oil. The type of filter used in a particular system depends on the size and type of the smallest particle to be removed. A full-flow filter is one which filters all of the oil which passes through the pumps. Such a filter is provided with a relief valve to allow bypassing of the oil if the filter element is clogged. A bypass filter is one which filters only a portion of the oil passing through a pump. As a rule, bypass filters are designed to remove finer particles than the full-flow type.

Some power drives use disposable, cartridge type filters, such as the one illustrated in figure 5-27 for the 5"/54 drive. These require no maintenance except occasional replacement of the cartridge.

Figure 5-31 shows a full-flow filter of the metal plate type. It is made up of metal discs through which the oil is filtered. Two filter elements are mounted on a common inlet and outlet manifold. A hand-operated lever permits one or the other of the elements to be placed in use. A self-cleaning device consisting of blades which can be rotated between the cleaning discs is incorporated. Sludge removed from the elements in this manner collects at the bottom of the unit, and should be frequently drained out.

This filter can be cleaned by removing the filter element from the case. Back off on the stud screw at the base of the element enough to permit some looseness between the discs. Flush element thoroughly with an approved fluid.

An example of the other type filter (bypass) is shown in figure 5-32. This filter consists of a cylinder containing a filter element made up of a number of packs of perforated paper discs. Spring action maintains a uniform pressure on each of the packs. Oil passes from the outside of the pack (where foreign matter is deposited) to the center passage, and through the outlet at the head of the filter.

The filter is so designed that the head, with all the filter packs attached, can be lifted as a unit from the body of the filter. To clean this type of filter, remove the element as above and connect a low pressure air supply to the oil outlet of the system. This allows the air to blow back through the element. When a white foam appears along the entire length of the pack, it is clean.

FLUSHING AND FILLING THE UNIT

The transmission system of the power drive should be flushed and refilled with new fluid whenever any of the following conditions exist:

1. Tests, usually performed by a repair ship or shipyard, indicate that the fluid has oxidized and become so acid that it is no longer suitable for use.

2. Examination of contaminants removed from filters and low points in the system reveals the presence of corrosion or an excess of metal particles.

3. A condition exists which necessitates cleaning of filters oftener than once a week.

4. New or repaired components are placed in a system.

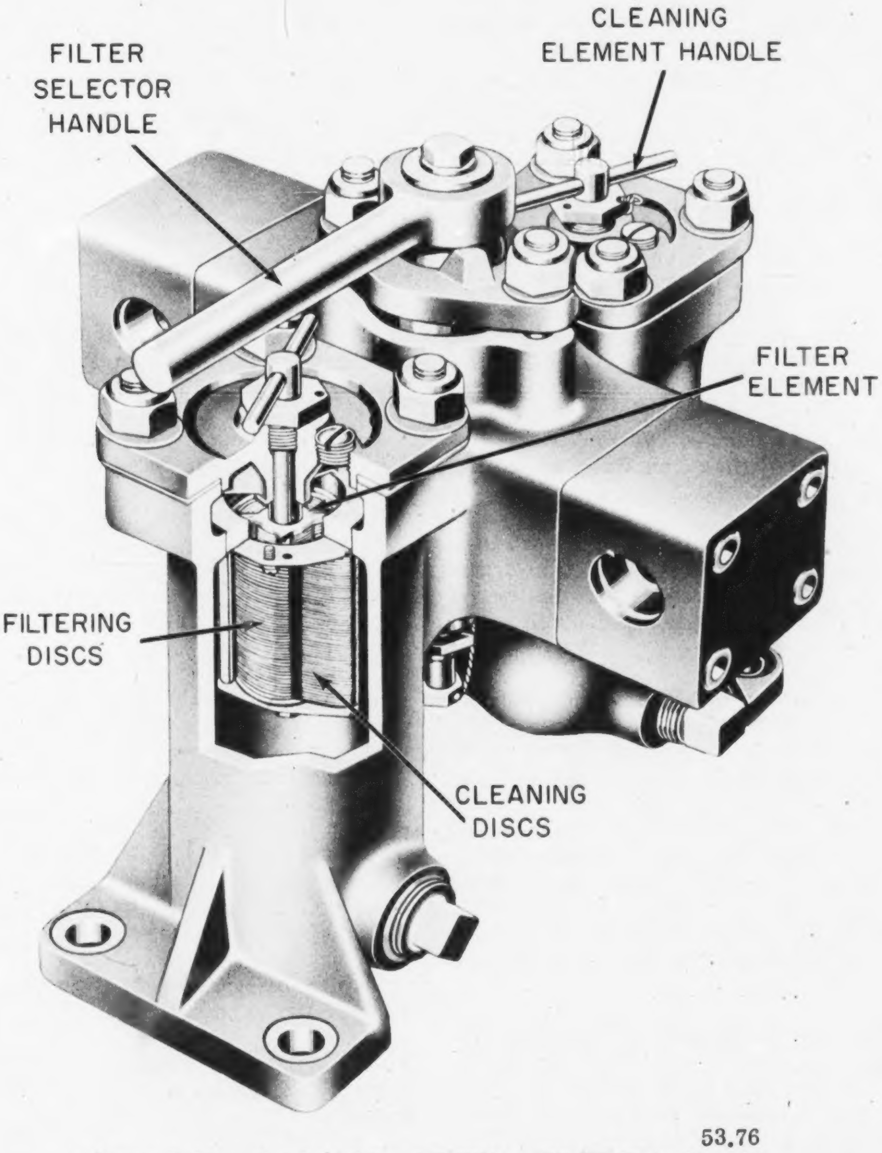
Listed in OD 3000 are several approved flushing fluids. In the interest of economy, however, reclaimed fluids should be utilized for this purpose.

While being flushed, hydraulic systems can be operated to raise the temperatures of the fluid.

Immediately after the warmup period, the system should be drained by opening all drain outlets.

Care should be taken when refilling the system with new oil. Foreign matter is most likely to be introduced in the system during this operation. Dirt and chips can be introduced into a system through drain plugs, filler caps, or hose nozzles.

Never put oil into a system without first passing it through a 200-mesh screened funnel. Never use cloth or rags to filter hydraulic fluid.


CLEANING ELEMENT HANDLE
FILTER SELECTOR HANDLE
FILTER ELEMENT
FILTERING DISCS
CLEANING DISCS

53.76
Figure 5-31.—Replenishing Oil Filter (5"/38 Twin Mount).

Examples of good and bad practice when performing this operation are shown in figure 5-33.

ADJUSTMENTS

Initial adjustments of the power drive are made at the time of installation with the aid of special gauges and instruments. Subsequent adjustments aboard ship should be undertaken only after competent personnel have determined that such adjustments are necessary. For detailed instructions to accomplish necessary adjustments, you must refer to the appropriate OP for the equipment.

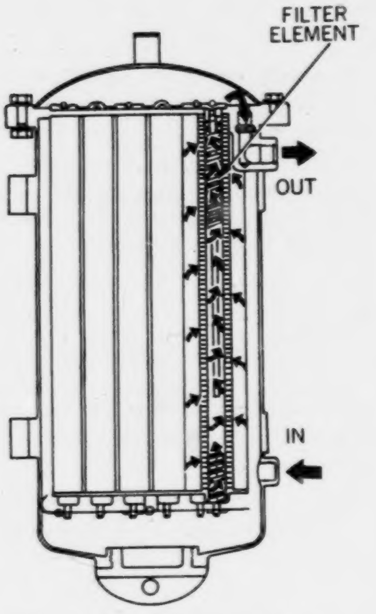


Figure 5-32.—Auxiliary Bypass Filter. 53.77

SAFETY

1. Always stop motors before working on equipment. If it is necessary to observe equipment in operation, stand clear of moving components.

2. Do not operate equipment without ensuring that all personnel are clear of moving components.

3. Whenever any motion of a power-driven unit is capable of inflicting injury on personnel or material not continuously visible to the person controlling such motion, the officer or petty officer who authorizes the unit to be moved by power shall, except at general quarters, ensure that a safety watch is maintained in areas where such injury is possible both outside and inside the unit, and shall have telephone or other effective voice communications established and maintained between the station controlling the unit and the safety watch. These precautions are applicable to all types of ordnance and, if more than one safety watch is used, the station controlling the ordnance shall obtain a "all clear" report from each safety watch before starting any motors.

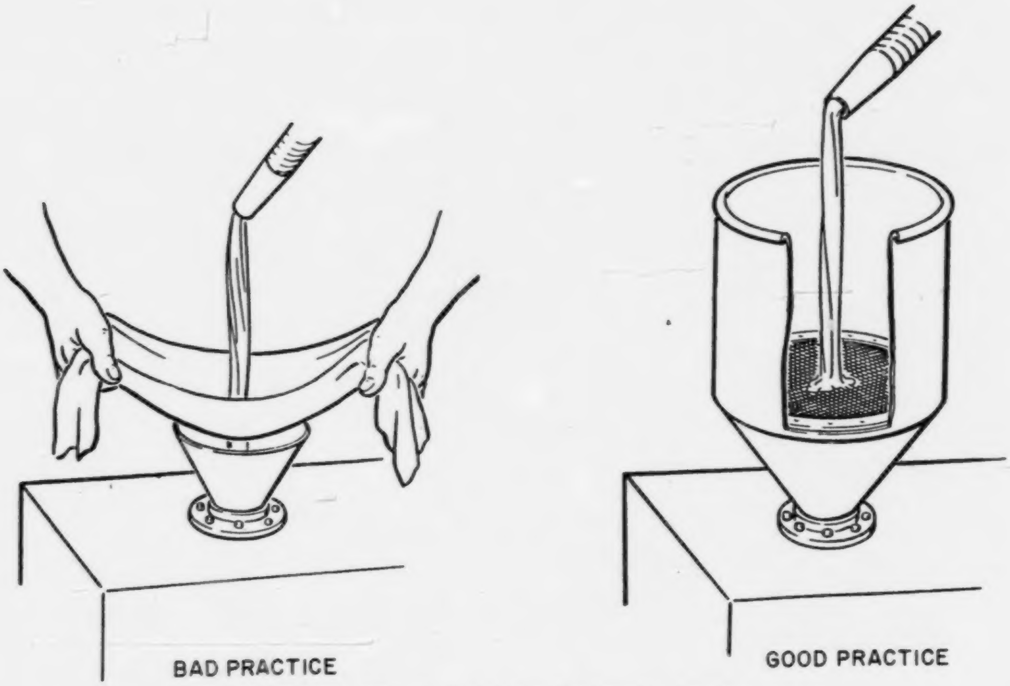


Figure 5-33.—Filling the Hydraulic System. 5.19

Each safety watch shall keep his assigned area clear and, if unable to do so, shall immediately report his area fouled, and the controlling station shall promptly stop the unit until all is clear.

4. Personnel shall not perform repairs or adjustments on energized mechanical or electrical equipment capable of inflicting injury except in cases where the repair or adjustment cannot be accomplished with the equipment deactivated. When such repairs or adjustments must be performed on energized equipment, an additional man who is familiar with procedures for emergency deactivation of the equipment, and capable of rendering aid, shall be stationed nearby for the duration of the repairs and adjustments.

5. A danger circle shall be established around all power driven ordnance units. The danger area shall be painted a distinctive color and labeled as a danger area. All ship's structure within 18 inches of the vertical extension of the danger circle to a height of seven feet shall be painted and labeled as a danger area.

6. Wipe up any spilled hydraulic fluid immediately. Do not allow the temperature of hydraulic fluid to exceed 190° F.

7. An electrical spark generated near overheated hydraulic fluid can cause a fire or an explosion.

8. If clothing becomes drenched with hydraulic fluid, change into dry clothing immediately. When in prolonged contact with the skin, hydraulic fluid can injure health.

9. Accumulator flasks are charged with nitrogen or compressed air, depending on the type system installed. If nitrogen is not available, accumulators can be recharged with compressed air. However, all nitrogen accumulator systems must thereafter be purged of the compressed air and recharged with nitrogen as soon as it is available.

10. Never charge accumulator flasks with oxygen. An oxygen and oil mixture is extremely explosive.

CHAPTER 6

HYDRAULIC CONTROL EQUIPMENT

In this chapter, we will study the equipment used to control hydraulic power drives. First, we take up the control equipment used with the 5"/38 gun system and then discuss that used with the 5"/54 system. We also will explain the applications of electronic servosystems and discuss how servoamplifiers control power drives.

The major element in the control equipment for the 5"/38 twin mount is the indicator-regulator. This is a basically standard instrument, manufactured by the Ford Instrument Company, and is similar in principle to the automatic control instruments used in many other installations in the fleet. We will discuss this instrument here in some detail, and show the operation of its components in all of the four different types of control which can be used. Included at the end of the chapter are some general pointers to help you in maintaining the equipment.

METHODS OF CONTROL

The 5"/38 twin mount has four methods of control: AUTOMATIC, LOCAL, HAND, and MANUAL. The type of control to be used is selected at the pointer's and trainer's stations by means of a selector lever. Just above the control selector lever is a speed selector lever, used to engage one or the other of two sets of gears which give different values of gun movement for each turn of the handwheels. As the handwheels are not used in AUTOMATIC, the speed selector will not affect that type of control.

In automatic control, a signal from a remote source, received electrically at the indicator-regulator, controls hydraulic valves in the indicator-regulator. These valves control the output to the hydraulic pump (A-end) which, in turn, controls the output of the hydraulic motor (B-end), causing the guns to automatically follow the remote signal with negligible error (fig. 6-1).

In local control, the indicator-regulator performs the same function as in automatic except that a mechanical signal, produced by rotation of the handwheel assembly (local signal), is used instead of the electrical remote signal (fig. 6-1).

In hand control, the indicator-regulator is bypassed. The handwheels control, by direct means, the output of the hydraulic pump (A-end) and, consequently, the position of the guns (fig. 6-1).

In the above three methods the hydraulic pump (A-end) is driven at a constant speed through the reduction gears by an electric motor. In case of failure of the electric motor or its source of power supply, a manual drive is provided.

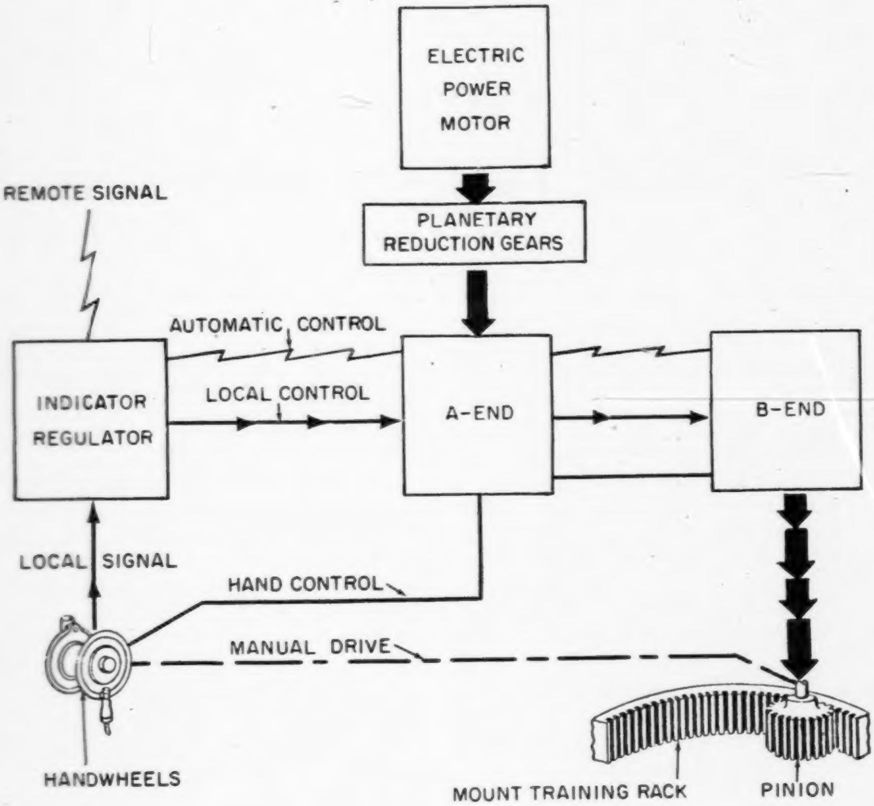
In manual drive, the guns are moved directly by the effort applied to the handwheels which are geared directly to the training racks, bypassing the entire power drive units. While the indicator-regulator does not operate in hand or manual, its indicator section continues to display gun mount positions (B-end response) and may continue to receive gun order position signals from the director.

INDICATOR-REGULATOR

The indicator-regulators are mounted on the handwheel drive assembly of the elevating and training gear system which they control. For simplicity we will describe only the Train Indicator-Regulator Mk 46, showing the major differences between it and the elevation indicator-regulator as we go along.

The indicator-regulator components may be divided into three groups: indicating section, electrical equipment, and control equipment.

The indicator-regulator converts an electrical or mechanical signal into an equivalent power drive control action. In completely automatic control, the gun director sends electrical gun order signals to the indicator-regulator (in train only, parallax is also received and combined with gun order). The signals are received by devices in the regulator that compare the


ELECTRIC POWER MOTOR
PLANETARY REDUCTION GEARS
REMOTE SIGNAL
AUTOMATIC CONTROL
INDICATOR REGULATOR
LOCAL CONTROL
A-END
B-END
LOCAL SIGNAL
HAND CONTROL
MANUAL DRIVE
HANDWHEELS
MOUNT TRAINING RACK
PINION

53.273
Figure 6-1.—Methods of control.

signal with the existing position of the gun. Any difference between the signal and the existing gun position shifts a hydraulic pilot valve away from its neutral position, in a direction corresponding to the direction of the difference (gun error).

Displacement of the pilot valve from neutral causes movement of other valves in the indicator regulator. Pressure is ported to the main (stroking) piston, causing it to move in the main cylinder. The main piston is mechanically connected to, and therefore positions, the tilting box of the A-end pump. This action, as you will recall from the preceding chapter, causes delivery of a controlled amount of hydraulic driving power to the B-end motor.

As the B-end and the guns move, response is registered by the regulator and continuously compared with the gun order signal.

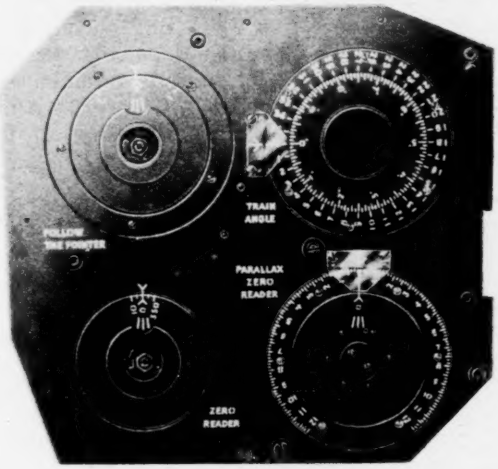
To better understand the operation of the indicator-regulator components in the different methods of control, let's examine them in more detail.

INDICATING SECTION

This section gives the operator an indication of three things: (1) incoming gun order signals, (2) position of the guns, and (3) correction readings—parallax (train only) and roller path inclination (elevation only). Figures 6-2 and 6-3 show the indicating sections of both train and elevation indicator-regulators.

Gun Order Indicators

Gun order signals are received electrically from the director system by two synchro motors. One is the fine indicating synchro motor which

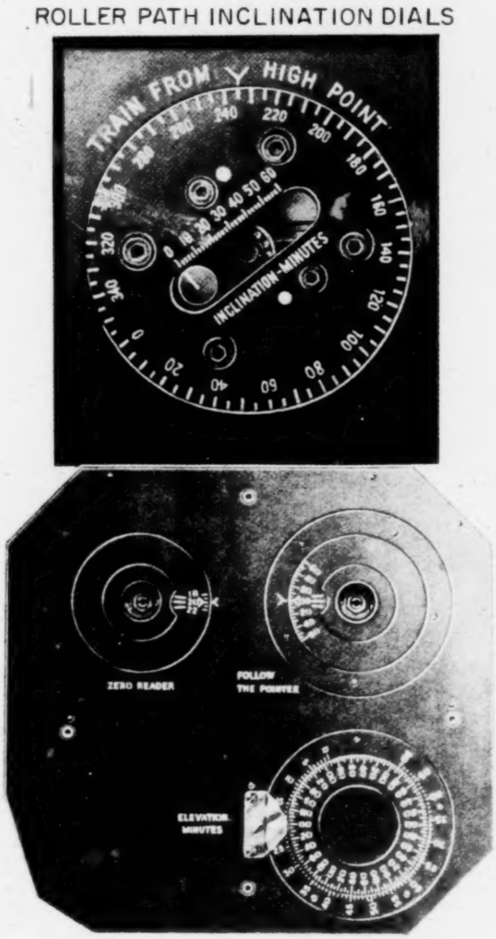


53.274
Figure 6-2.—Train dials.

rotates at 36 speed—that is, one revolution of the motor represents 10° of gun movement. The other motor, called the coarse indicating synchro motor, rotates at 1 speed (one revolution of the motor represents 360° of gun movement.

The rotor of the coarse synchro is attached to the ZERO READER DIAL. As the coarse synchro rotates at 1 speed, the zero reader dial gives a coarse reading of gun order signal. The stator of the coarse synchro is rotated in an opposite direction to that of the rotor by corrected mount response from the B-end. Because the rotor is carried with the stator, the zero reader dial will be aligned with the fixed pointer when the signal has been satisfied (that is, when mechanical response is equal to gun order).

The rotor of the fine indicating synchro is connected to the inner (disc) dial of the FOLLOW-THE-POINTER dial. The outer (ring) dial is connected to the mechanical response. As the fine synchro motor rotates at 36 speed, the follow-the-pointer dial gives a very exact reading of gun order. But remember that the inner dial, being 36 speed, will be aligned with the ring dial index whenever the gun order signal differs from gun position by any multiple of 10°. Therefore, the fact that the indexes of the inner and outer dials are matched does not mean that the signal is satisfied unless the ZERO READER dial is matched with its index.



110.83(53C)
Figure 6-3.—Elevation dials.

Gun Position Indicators

Gun position is registered on a ring and inner dial assembly. These dials are driven by mechanical response from the B-end.

The dial assemblies are marked at their respective indicator regulators as TRAIN ANGLE and ELEVATION MINUTES. The outer ring dials are rotated at 1 speed and are graduated in large increments. The inner dials are rotated at 36 speed and give a more accurate reading, being graduated in smaller increments. Both inner and ring dials are read together against their fixed indexes for accurate readings.

Correction Indicators

PARALLAX CORRECTION INDICATOR.—Horizontal parallax is the angle formed in the horizontal plane, at the target, by the intersection of the lines of sight from each of two stations. These stations are, so far as you are concerned, the director and the gun mount. Most guns are located some distance from the director. Their lines of sight, if they are following the director perfectly, will be parallel and will not intersect at the target. Therefore, correction for parallax must be added to the gun train angle at each mount, so that the lines of sight of the gun and director will intersect at the target.

The parallax correction signal will be received at the indicator regulator as UNIT parallax. Unit parallax is defined as a horizontal parallax correction of the magnitude and direction, for any given range and bearing, that would correct the train angle of an imaginary gun located 100 yards from the director. Change gears in the indicator regulator reduce this signal to true gun parallax correction at each mount.

Parallax may also be introduced into the indicator-regulator manually, by turning a handcrank. Selection of automatically or manually introduced parallax is made by shifting the 2-position parallax handcrank knob.

On most indicator-regulators, the disc dial of the parallax indicator is marked with special graduations which facilitate the firing of illuminating projectile search spreads. By placing the parallax selector in manual, and spacing the graduations at selected different settings for the various mounts, the desired spread of train angles can be obtained.

ROLLER PATH INCLINATION INDICATOR.—This dial is found in the elevation indicator-regulator only. It indicates the inclination of the mount roller path from the horizontal, and the degree of mount train from the highest point of inclination. We will discuss this device in detail in chapter 7.

Star Shell Signal Indicators

These are merely lamps located in the face of the indicating section. They are lighted whenever the mount is ordered to fire illuminating projectiles and therefore does not follow the same director signals as the rest of the battery.

NOTE: While they are located in the same indicator regulator, the indicating synchros we have just discussed should not be confused with the control synchros which actually control movement of the guns in automatic. Control synchros will be shown in more detail later in this chapter.

REGULATOR ELECTRICAL EQUIPMENT

The major elements of the electrical equipment are synchros. In the indicating section of the indicator-regulator they act to receive gun orders (and parallax) and indicate these orders by rotation of affixed disc dials.

In the control section of the indicator-regulator, the synchros act to receive gun orders from the director. By action of the synchro rotors, the electrical signal is converted to a mechanical one. The rotors mechanically operate the fine and coarse pilot valves.

REGULATOR CONTROL EQUIPMENT

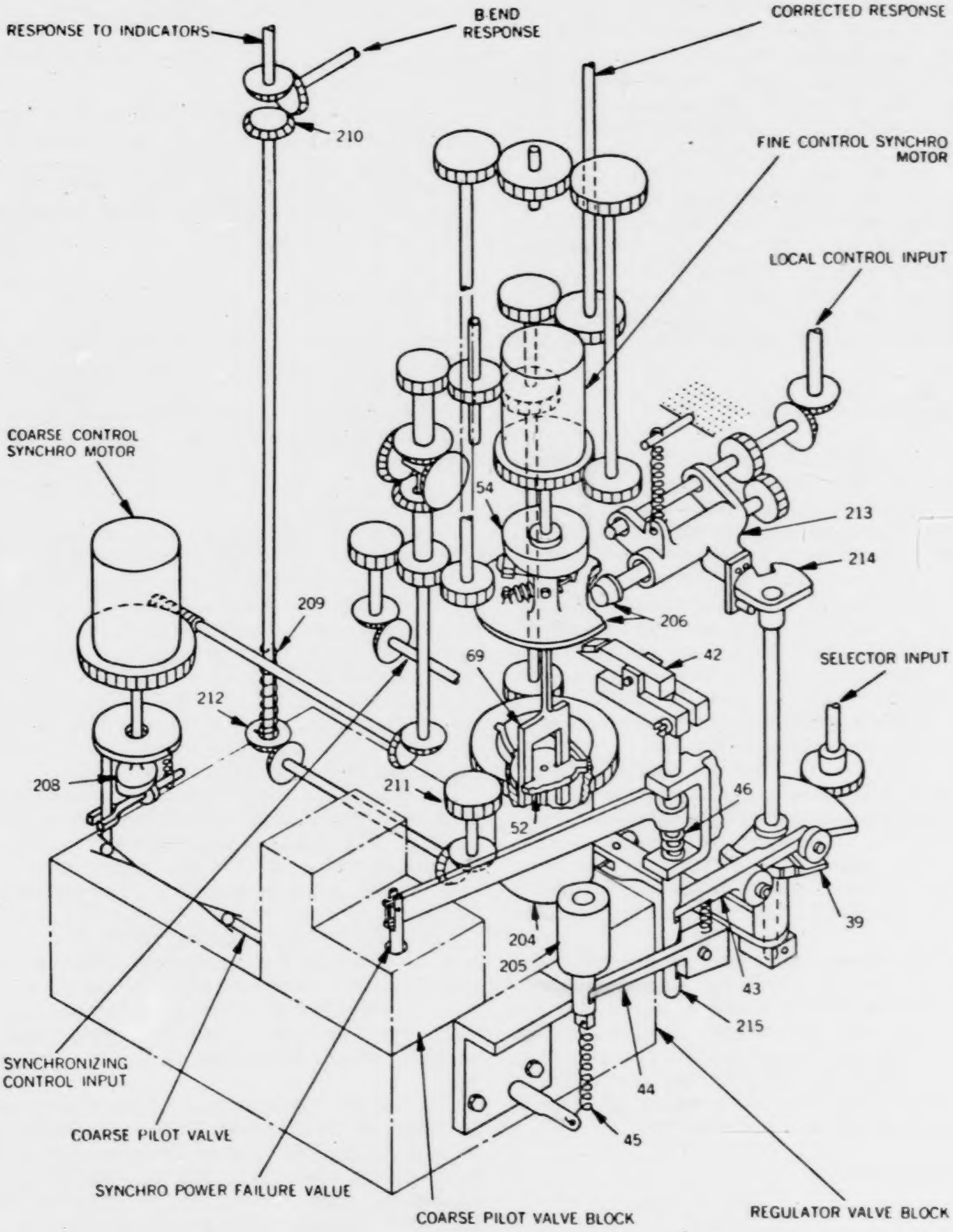
The control equipment of each indicator-regulator receives gun orders (electrically in automatic control and mechanically in local control), gun response, parallax corrections in train, and roller path tilt in elevation. The equipment combines these inputs to produce a variable flow of liquid to or from the regulator valve block and the main piston and cylinder. As a result of these actions, the A-end tilting boxes are positioned to control movement of the guns. A gear schematic diagram of the receiver regulator is shown in figure 6-4.

Fine and Coarse Control Synchros

In automatic control, gun orders from the director turn the rotors of the fine and coarse control synchros. The rotors mechanically operate the fine and coarse pilot valves which set the control devices in motion.

Relief Cam Assemblies

The purpose of these assemblies is to permit the fine and coarse control synchros to follow the gun order signals when the pilot valves have reached their limits of travel. The cylindrical relief cams 54 and 208, figure 6-4, are attached to the rotors of the fine and coarse control


RESPONSE TO INDICATORS
B END RESPONSE
CORRECTED RESPONSE
210
FINE CONTROL SYNCHRO MOTOR
LOCAL CONTROL INPUT
COARSE CONTROL SYNCHRO MOTOR
54
213
214
209
206
69
42
SELECTOR INPUT
212
208
211
46
52
39
204
205
43
215
44
45
SYNCHRONIZING CONTROL INPUT
COARSE PILOT VALVE
SYNCHRO POWER FAILURE VALUE
COARSE PILOT VALVE BLOCK
REGULATOR VALVE BLOCK

53.80
Figure 6-4.—Regulator schematic diagram.

synchro motors respectively. A cam follower roller, held against each cam by a tension spring, connects the cam mechanically to its pilot valve. When a gun order signal rotates the rotors of either the fine or coarse synchro, its cam and cam follower also rotates thereby positioning the pilot valve. The cams are made so that their contact surfaces rise uniformly from a low point. When there is a sudden change in the position of the cam by the rotors, due to a reversal of gun order at high speed, it will momentarily cause the cam follower roller to leave the low point of the cam. The tension spring will return the roller to the low point of the cam fairly rapidly but, in the interim the movement of the synchro will be prevented from reacting too violently on the hydraulic control system.

Differential Cam Assembly

The differential cam assembly, figure 6-5, compares gun order with gun position. It consists of a 2-pronged fork (69 fig. 6-5) attached through the relief cam assembly to the rotor of the fine control synchro, a 3-fingered cam follower (52 fig. 6-5), and the differential cam (204 fig. 6-5). The differential cam is a hollow cylinder with three grooves curving up and around its inside surface. The fingers of the followers slide in these grooves and the prongs of the fork extend down through slots in the follower. A shaft extends downward from the follower and is secured to the fine pilot valve.

When either the fork or the cam is rotated, the follower will move either up or down inside the cam, depending upon the direction of rotation. Thus reception of a signal by the fine control synchro will cause the rotation of the fork and follower. When the follower moves up or down, the attached fine pilot valve is also moved.

Mount movement (response) is geared to the differential cam in which the follower moves. As the mount moves to follow a signal, the response moves the differential cam, displacing the follower and the fine pilot valve in a direction opposite to that produced by the signal. This action returns the fine pilot valve to neutral when the gun order has been satisfied.

REGULATOR VALVE BLOCK

The main control valves of the indicator-regulator are housed in the regulator valve block. These valves include the fine pilot valve, the amplifier valve, the acceleration valve, the main valve, and the selector valve, figure 6-6.

Fine Pilot Valve

The fine pilot valve (V-FP) (fig. 6-5) is positioned mechanically by the output of the differential cam (the difference between corrected gun order and actual gun position). It is located inside the amplifier valve and hydraulically controls its position.

Amplifier Valve

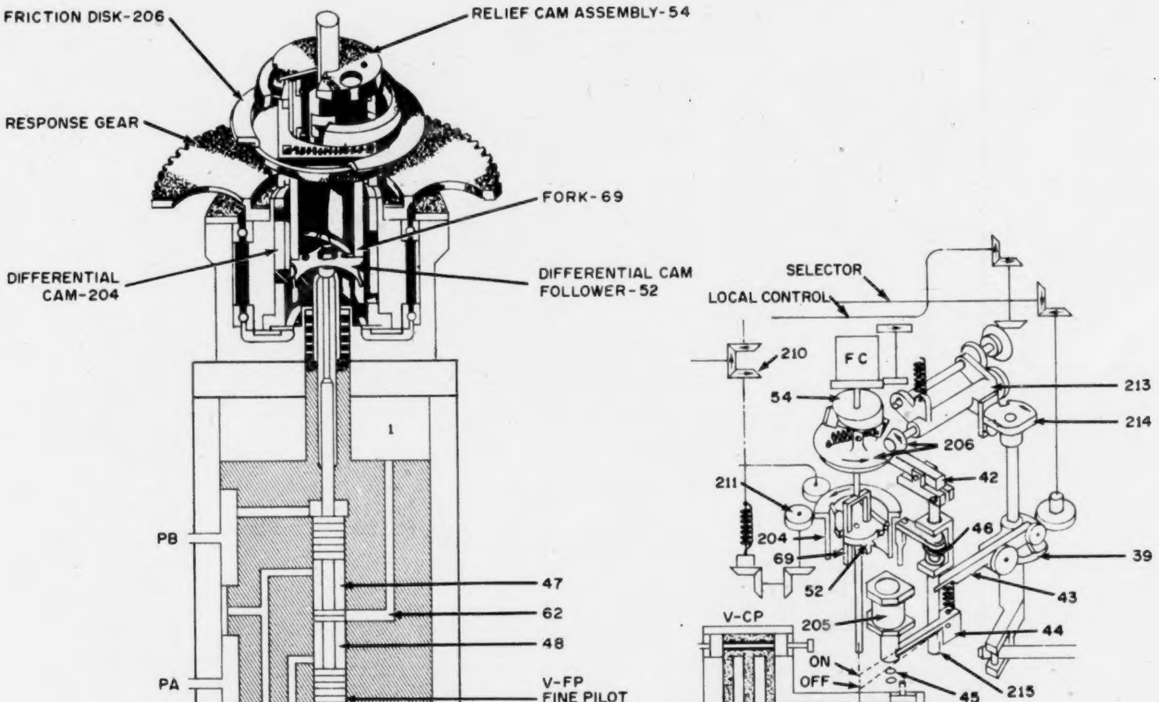
The amplifier valve (V-AM) (fig. 6-5) is controlled by, and has the same motion as, the fine pilot valve. With both the fine pilot valve and the amplifier valve in their neutral positions (fig. 6-5), the center land of V-FP closes the port leading from passage 62 to chamber 1 at the top of V-AM. (Pressures in chambers 1 and 2 are equal.)

A difference between gun order and gun position will result in an upward or downward movement of V-FP from its neutral position. Movement of V-FP upward ports chamber 1 to PX (exhaust) decreasing the pressure in chamber 1 and causing V-AM to move upward. Downward movement of V-FP from its neutral position would port chamber 1 of V-AM to P1, increasing the pressure in chamber 1 and forcing V-AM downward. The amplifier valve thus follows the movement of the fine pilot valve.

Movement of amplifier valve V-AM causes flow of liquid into or out of chamber 2. Movement of PR1 liquid is important as it is directly concerned with control of the acceleration valve, main valve, main piston and, subsequently, the A-end tilting box.

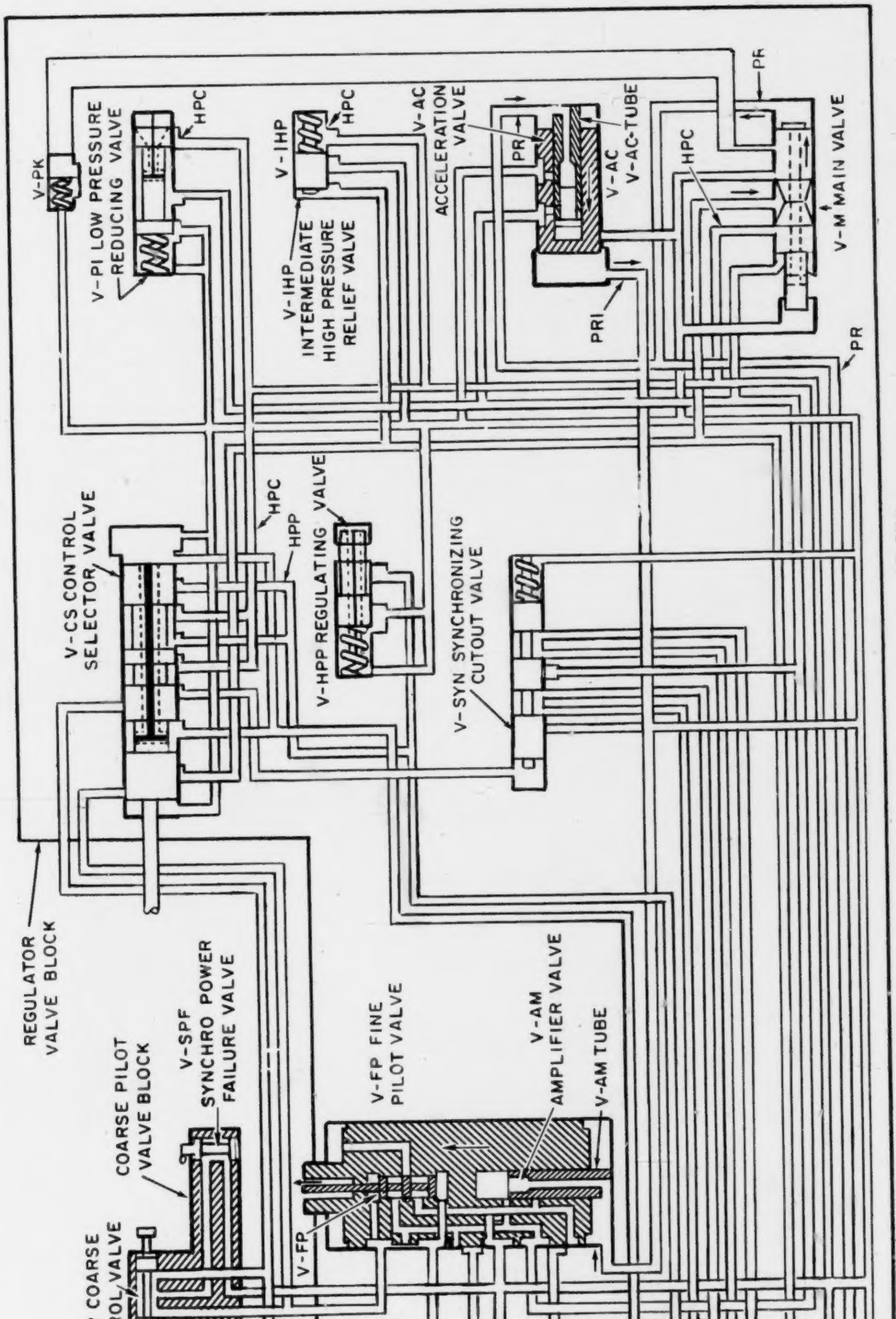
Flow of oil into and out of chamber 2 (fig. 6-5) is aided by the stationary amplifier valve tube. Upward movement of V-AM ports chamber 2 to PX through slot 65 port 63 and passage 57. More liquid then leaves the PR1 system than the unaided upward movement of V-AM could draw in.

Downward movement of V-AM from neutral connects P1 to chamber 2 through slot 65 port 64 and passage 56. Liquid from the P1 system then enters the PR1 system, increasing the amount of fluid flowing out of chamber 2 into the PR1 system. Change in pressure in the PR1 system is negligible when connected to P1 or PX due to the narrowness of slot 65.


FRICTION DISK-206
RELIEF CAM ASSEMBLY-54
RESPONSE GEAR
FORK-69
DIFFERENTIAL CAM-204
DIFFERENTIAL CAM FOLLOWER-52
1
PB
47
62
48
PA
V-FP FINE PILOT VALVE
151
V-AM AMPLIFIER VALVE
PBI
57
PX
64
56
PI
63
PAI
V-AM TUBE-65
152
2
PRI
66
SELECTOR
LOCAL CONTROL
210
FC
213
54
214
206
211
42
204
46
69
39
52
43
V-CP
205
44
ON
OFF
45
215
V-SPF
L11
1
V-FP
2
V-AM TUBE

53.83(53C)

Figure 6-5. — Differential cam, and amplifier valve assembly.


V-PK
V-PI LOW PRESSURE REDUCING VALVE
HPC
V-IHP
HPC
V-IHP INTERMEDIATE HIGH PRESSURE RELIEF VALVE
V-AC ACCELERATION VALVE
PR
V-AC
V-AC-TUBE
PRI
PR
HPC
V-M MAIN VALVE
PR
V-CS CONTROL SELECTOR VALVE
HPC
HPP
V-HPP REGULATING VALVE
V-SYN SYNCHRONIZING CUTOUT VALVE
REGULATOR VALVE BLOCK
COARSE PILOT VALVE BLOCK
V-SPF SYNCHRO POWER FAILURE VALVE
V-FP FINE PILOT VALVE
V-AM AMPLIFIER VALVE
V-AM TUBE
V-CP COARSE CONTROL VALVE
V-FP

53.275
Figure 6-6.—Regulator valve block.

To study the function of the acceleration valve and main valve, refer to figure 6-7.

Acceleration Valve

The acceleration valve (V-AC) and the amplifier valve (V-AM) function together as a hydraulic amplifier increasing the quantity and pressure of liquid flow.

The acceleration valve body acts as a free-moving valve. As the areas of chambers 3 and 4 at opposite ends of the acceleration valve are equal, the pressures PR and PR1 are equal. It is apparent then that movement of this valve is controlled by the flow of liquid into and out of the chambers. Chamber 3 is directly connected to the bottom chamber of the amplifier valve (chamber 2). Unless the amplifier valve operates to increase or decrease the amount of liquid in chamber 3 of the acceleration valve, the position of the acceleration valve remains unchanged.

Movement of V-AC causes flow of PR liquid into or out of chamber 4 of the acceleration valve. This flow is augmented (amplified) by the action of the acceleration valve tube described below.

The acceleration valve tube is similar to the amplifier valve tube in design and operation.

As the amplifier valve moves upward drawing PR1 liquid from chamber 3 of the acceleration valve into its own chamber 2, the acceleration valve body moves to the left, increasing the volume of chamber 4. This movement connects the PR system to PX through the slot in the V-AC tube and the port in the valve body, while the port in the P1 system is closed off. As a result an augmented flow of liquid in the PR system takes place.

When the amplifier valve moves down, the reverse action takes place forcing the acceleration valve body to the right into chamber 4. This opens P1 to the PR system and augments PR flow.

PR pressure will remain practically the same throughout all the above operations, being immediately balanced by the action of the main valve (V-M).

Main Valve

The main valve (V-M) is hydraulically controlled by the acceleration valve and the response piston (P-R). It hydraulically positions the main (stroking) piston which mechanically positions the A-end tilting box.

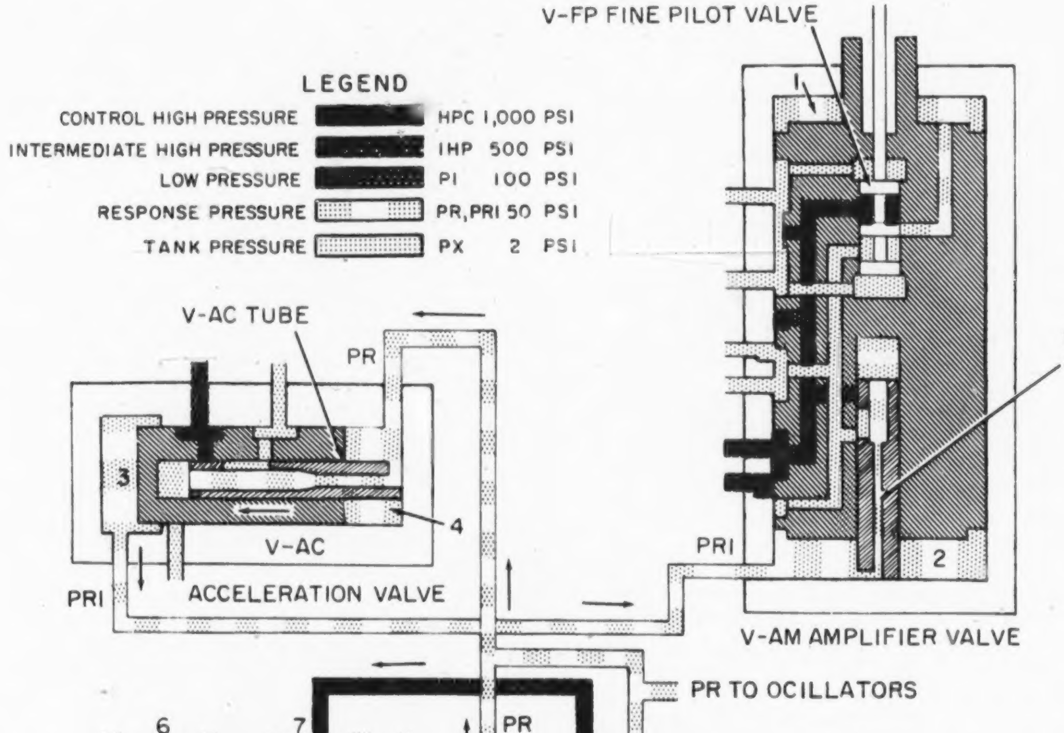
Chamber 4 at the acceleration valve is connected to chamber 5 at the main valve. Chamber 6, located at the opposite end of V-M, is connected to P1 (maintained at a constant pressure). The main valve will remain stationary if there is no movement of the amplifier or acceleration valves. Since P1 in chamber 6 is constant, it is evident that the movement and position of the main valve is controlled by liquid flow in chamber 5. When liquid flows out of chamber 5, the main valve moves to the right. Chamber 7 becomes connected to PX. A flow of liquid into chamber 5 moves V-M to the left, connecting chamber 7 to HPC. Thus a pressure designated intermediate high pressure (IHP), is generated in chamber 7. With the main valve at neutral, both the ports of HPC and PX are open by equal and very slight amounts. With HPC being 1000 psi (train) and PX being zero, the pressure formed in chamber 7 would be 500 psi, assuming the main valve is at neutral.

If the main valve is moved to the right (by liquid flowing out of chamber 5), IHP will become less than 500 psi, as it is opened to PX and HPC is closed off. Likewise, if the main valve is moved so that the port supplying HPC to chamber 7 is opened a greater amount, the port connecting PX is more nearly closed. In this case IHP will become greater than 500 psi.

IHP, originated and controlled at the main valve, is connected by piping to a chamber at one side of the main piston. The other side of the main piston is connected to HPC which is held constant at 1000 psi. Since the area upon which HPC acts is exactly one-half the area upon which IHP acts, the main piston will be held fixed in one position when IHP is one-half of HPC. Whenever IHP varies from its normal value of one-half HPC because of motion of the main valve, the main piston will move. Movement of the main piston moves the A-end tilting box and the guns.

For simplicity of explanation we have purposely left the connection of PR to the response piston out of the picture until now. Because of the design of the main piston and response piston, you may consider that PR will not affect the balance obtained by HPC and IHP at the main piston. As soon as the main piston moves (the response piston moving with it), the change of volume in the PR line will be compensated for by the oil displaced by the response piston.

The reason for establishing an oscillatory effect in the hydraulic control system was explained in the last chapter. This effect is introduced by the sump pump and oscillator into the


V-FP FINE PILOT VALVE
LEGEND
CONTROL HIGH PRESSURE HPC 1,000 PSI
INTERMEDIATE HIGH PRESSURE IHP 500 PSI
LOW PRESSURE PI 100 PSI
RESPONSE PRESSURE PR,PRI 50 PSI
TANK PRESSURE PX 2 PSI
1
V-AC TUBE
PR
3
4
V-AC
ACCELERATION VALVE
PRI
V-AM TUBE
PRI
2
V-AM AMPLIFIER VALVE
PR TO OCILLATORS
PR
6
7
5
V-M MAIN VALVE
P-M MAIN STROKING PISTION
MAIN CYLINDER
8
P-R RESPONSE PISTON
10
A-END
PR
9
V-MC MAIN CYLINDER RELIEF VALVE
RESTRICTING ORFICE

53.84

Figure 6-7.—Regulator hydraulic control circuit.

PR system. The motion is imparted to all of the valves described so far.

Selector Valve

Before we undertake the study of the four methods of controlling the power drive, we will explain the operation of the selector valve. This important valve is used as a hydraulic switch to make various hydraulic connections throughout the system as necessary for the different types of control. It is mechanically positioned by means of the control selector lever on the handwheel drive assembly.

The following pressures are involved in the action of the selector valve:

1. Pump high pressure (HPP)—train psi 1000, elevation psi 500
2. Control high pressure (HPC)—train psi 1000, elevation psi 500
3. Intermediate high pressure (IHP)—in neutral 1/2 of HPC
4. Low pressure (PI)—psi 100
5. Tank pressure (PX)—approximate psi 2

In the AUTOMATIC CONTROL position (fig. 6-8A), HPC is originated at the selector valve by being connected to pump high pressure (HPP). The hand control clutch operating piston (P-HCC) in the A-end control unit is connected to tank pressure PX and thus disconnects the handwheels from the A-end control unit. Also in this position the selector valve delivers HPC to the synchronizing control valve, placing the synchronizing control device in a position to respond to changes in the amplifier valve.

In figure 6-8B, the selector valve has been shifted to the right by placing the control selector lever in LOCAL. Pump high pressure (HPP) remains connected to HPC, keeping the A-end tilt under control of the regulator system. P-HCC in the A-end control unit is connected to PX keeping that unit still disconnected. The two ends of the fine pilot valve are connected to tank pressure, preventing the coarse pilot valve (V-CP) from building up pressure PI at V-FP in a way to cause it to operate. The synchronizing control device is made inactive by connecting it to PX.

When the control selector lever is moved to LOCAL, the handwheel drive is connected to the fine pilot valve. Rotation of the handwheels therefore controls the regulator and the power drive through the fine pilot valve.

In hand operation, the selector valve is positioned as shown in figure 6-8C. The control high pressure and the intermediate high pressure are connected to tank pressure. The regulator, therefore, no longer exerts control over the main piston and the power drive. With pressure removed, the main piston offers no resistance to movement of the A-end tilting box. The selector valve now delivers HPP to the hand control clutch and enabling the handwheels to control the power drive through the A-end control unit.

In the MANUAL position (fig. 6-8D), the selector valve is moved still further right, and all pressures controlled by the valve are connected to tank pressure. This action renders not only regulator control but the entire hydraulic power drive inoperative. At the same time, movement of the control selector lever engages the manual drive clutch. The guns now can be operated only through mechanical means by rotation of the handwheels.

METHODS OF OPERATION

Before commencing the study of methods of control, we will restate two facts about automatic and local control:

1. The function of the hydraulic control system is to bring about controlled motion of the main piston, and thereby controlled motion of the guns in accordance with some signal.

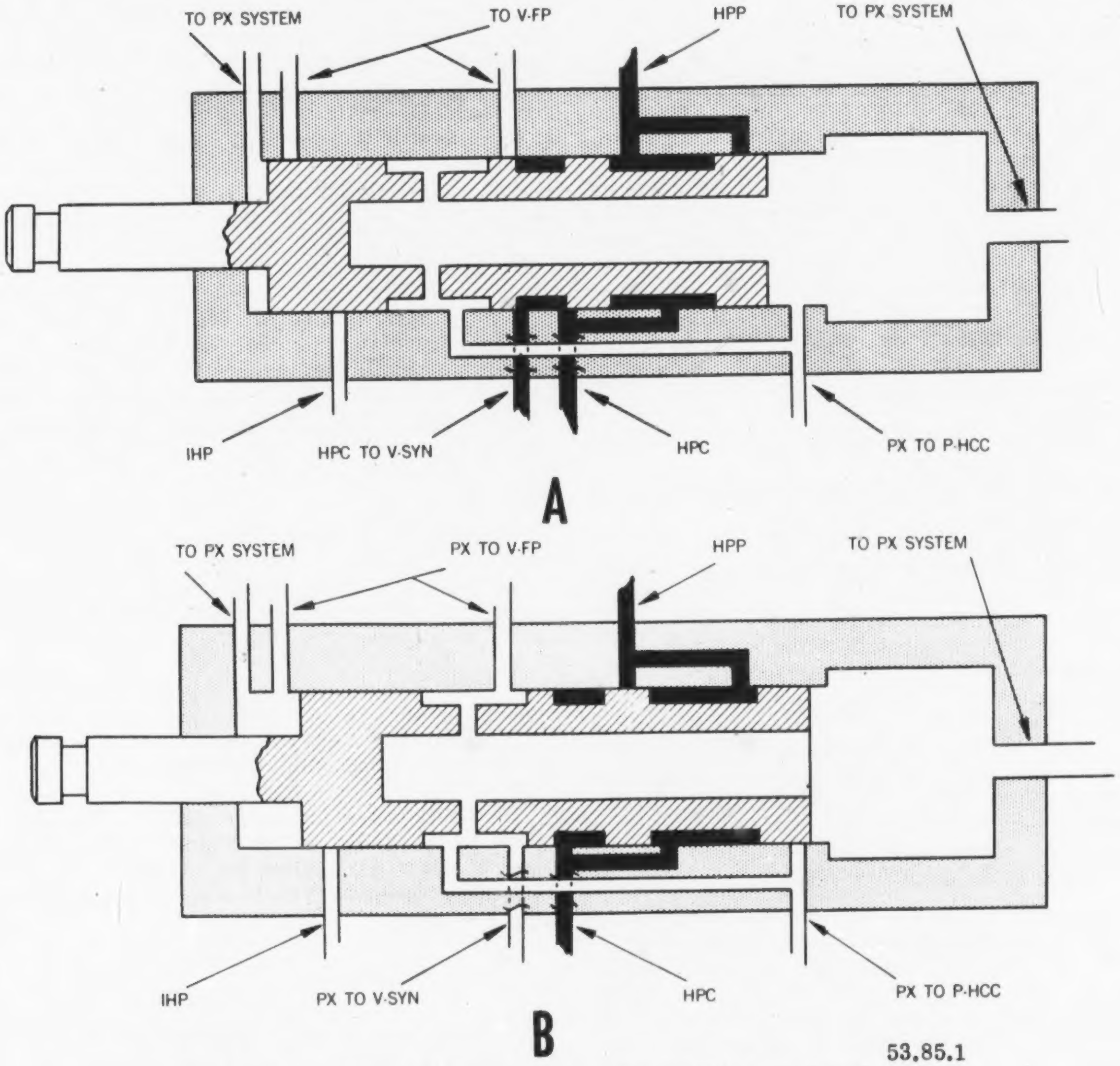
2. At all times the main valve will be positioned by the change in PR volume. (This is done in such a way as to allow the change in PR volume to be taken care of by the movement of the response piston.)

Automatic Control

Placing the control selector lever in the AUTOMATIC position removes the handwheels from the control picture.

The incoming electrical gun order signals received by the control synchros produce relatively weak rotary motions. Through the action of the fork attached to the fine control synchro rotor and the differential cam assembly, the cam follower is caused to move up or down. Attached to the cam follower is the fine point valve.

Return to figure 6-7 and assume that the incoming signal is such that the fine pilot valve is drawn upward. Chamber 1 at the top of the amplifier valve is opened to PX, allowing the


TO PX SYSTEM
TO V-FP
HPP
TO PX SYSTEM
IHP
HPC TO V-SYN
HPC
PX TO P-HCC
A
TO PX SYSTEM
PX TO V-FP
HPP
TO PX SYSTEM
IHP
PX TO V-SYN
HPC
PX TO P-HCC
B

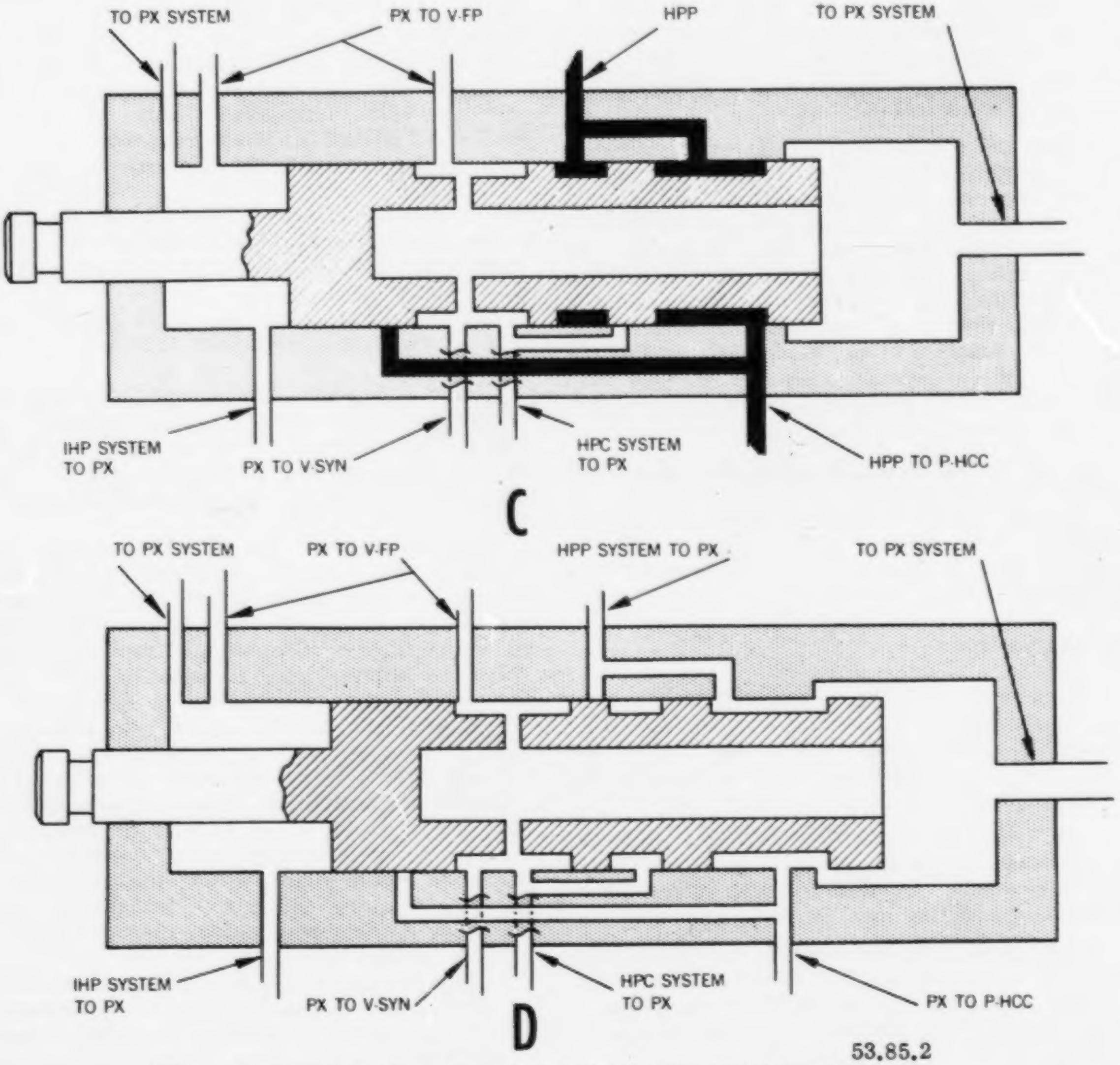
53.85.1

Figure 6-8.—Selector valve A. Automatic position B. Local position.

amplifier valve to move upward. Liquid is drawn from the PR1 system into chamber 2 of the amplifier valve. This flow is aided by opening chamber 2 to PX through the slot in the amplifier tube.

As V-AM moves upward, drawing PR1 liquid from chamber 3 of the acceleration valve into its own chamber 2, the acceleration valve body moves to the left, increasing the volume in chamber 4. As the acceleration valve body moves to the left, PR is connected to PX through the slot in the acceleration valve tube, and the flow of liquid in the PR system is augmented.

As the acceleration valve body moves to the left, liquid is drawn into its chamber 4 from chamber 5 of the main valve. The main valve moves right, porting IHP at chamber 7 to PX. Reducing the pressure of IHP causes the main


TO PX SYSTEM
PX TO V-FP
HPP
TO PX SYSTEM
IHP SYSTEM TO PX
PX TO V-SYN
HPC SYSTEM TO PX
HPP TO P-HCC
C
TO PX SYSTEM
PX TO V-FP
HPP SYSTEM TO PX
TO PX SYSTEM
IHP SYSTEM TO PX
PX TO V-SYN
HPC SYSTEM TO PX
PX TO P-HCC
D

53.85.2

Figure 6-8.—Selector valve C. Hand position D. Manual position.

piston to move to the left in the main cylinder. This moves the tilting box in the direction to produce the required amount of right train. If a signal was introduced for left train, all of the actions described above would occur but in opposite directions.

Mechanical response acts as soon as rotation of the B-end starts. When the guns have caught up to the signal, mechanical response geared to the differential cam causes return of the fine pilot valve to neutral.

Local Control

Operation in local control is similar in many respects to automatic control. In both types of control the hydraulic control system governs the operation of the mount.

In local control, however, the fine pilot valve is controlled by rotation of the handwheels (fig. 6-1), and not by the electric signal received by the control synchros. The coarse pilot valve is disconnected from the system, and the synchronizing control device is hydraulically locked in its neutral position.

When the control selector lever is shifted to local, a notch in cam 214, figure 6-4, is positioned opposite a follower on the local control pivoted arm 213. The pivoted arm is moved as the follower enters the notch in the cam by spring action. This causes the roller to bear on a friction disc 206 mounted on the fork assembly 69 which rotates in and with the differential cam 204. Rotation of the handwheels rotates the roller 206 in contact with the friction disc 206 and, thereby, controls the motion of the fine pilot valve (V-FP fig. 6-5).

From this point the hydraulic control system functions as in automatic control.

In all types of control except local, the friction roller is held out of contact with the friction disc by the action of the notched cam and its follower.

Manual Control

In manual control the handwheels are connected directly to the training worm or elevating pinion by gears and shafts. Because of the load, the speed selector lever must be in the LOW position.

All hydraulic control pressures are opened to exhaust by action of the selector valve; therefore the spring-loaded brake valves act to position the tilting box to its ZERO position.

The hydraulic block between the B-end (rotated by response) and the A-end is eliminated by the action of the antioverhaul mechanism. This device was explained in the preceding chapter.

Hand Control

In hand control, motion of the handwheels positions the tilting box through the A-end control unit. The hydraulic control mechanism in the indicator-regulator is made inoperative by the action of the selector valve when the selector lever is in HAND position. The selector valve also connects both sides of the main piston to exhaust, thus eliminating resistance to movements of the tilting box. At the same time, the selector valve ports high pressure oil to the hand control clutch piston at the A-end control unit. A schematic of the A-end control unit is shown in figure 6-9. For the present, disregard the limit stop mechanism shown in the same illustration.

Notice that the control mechanism is a sort of differential arrangement with two inputs—handwheel motion and B-end response. The output, which represents the difference between the two, positions the tilting box. Note that gear 2 has a splined bore to fit the splined end of the screw control shaft. While the screw control shaft turns with gear 2, it is free to move laterally through it.

At its opposite end, the screw control shaft is a screw with a large lead. It is fitted through gear 1.

Rotation of gear 1 (while gear 2 is stationary) causes the screw control shaft to move laterally through the threaded bore of gear 1 and the splined bore of gear 2. Rotation of gear 2 will also rotate the screw control shaft and cause it to move laterally.

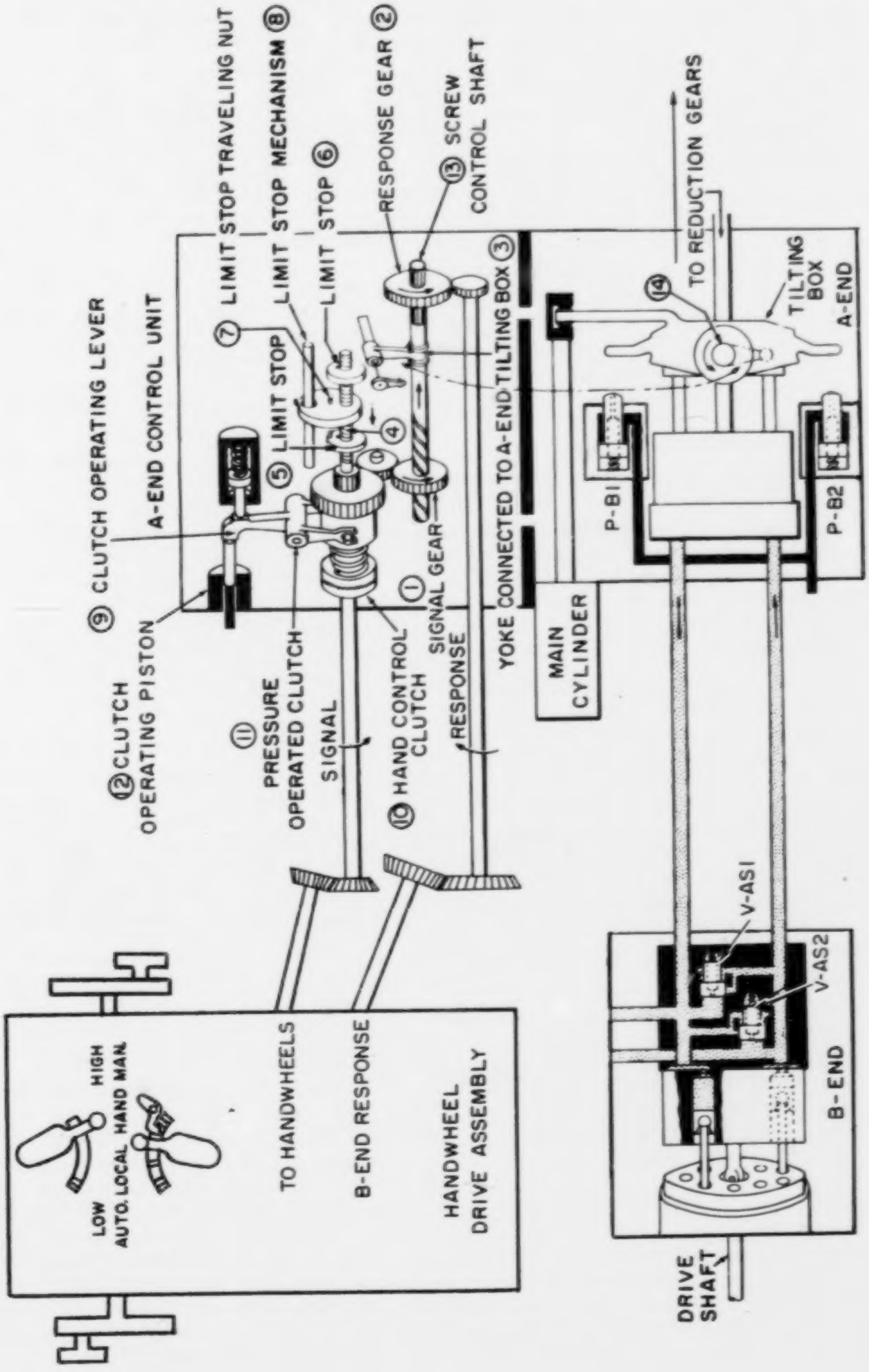
Assume now that the guns are at rest and a signal is introduced to the A-end control unit by rotation of the handwheels. This rotation is transmitted to gear 1 through the clutch which is held engaged by oil pressure from the selector valve. Rotation of gear 1 cannot by itself rotate the screw control shaft which is held by gear 2. Because of the lead of the screw, rotation of gear 1 results in lateral movement of the shaft through it and, thus, introduces an angle of tilt to the A-end tilting box. This will, as previously described, result in movement of the mount.

As soon as the mount moves, B-end response begins to rotate gear 2 in the same direction as gear 1. As long as gear 1 is rotating faster than gear 2, the screw control shaft will continue to move the tilting box.

When the angle of tilt is such that the mount is moving at a speed corresponding to the speed of rotation of the handwheels, the speed of gears 1 and 2 will be the same. Under these circumstances there will be no further lateral movement of the shaft. When the speed of gear 2 becomes greater than that of gear 1, the screw control shaft begins to return the tilting box to neutral, showing the speed of the B-end.

Limit Stop Mechanism

The limit stop mechanism (fig. 6-9) is located in, and acts in conjunction with, the A-end control unit. Its purpose is to stop the guns


⑨ CLUTCH OPERATING LEVER
A-END CONTROL UNIT
⑦ LIMIT STOP TRAVELING NUT
LIMIT STOP MECHANISM ⑧
LIMIT STOP ⑥
⑤ LIMIT STOP
④
RESPONSE GEAR ②
⑬ SCREW CONTROL SHAFT
YOKE CONNECTED TO A-END TILTING BOX ③
① SIGNAL GEAR
⑫ CLUTCH OPERATING PISTON
⑪ PRESSURE OPERATED CLUTCH
SIGNAL
⑩ HAND CONTROL CLUTCH
RESPONSE
MAIN CYLINDER
P-B1
P-B2
TO REDUCTION GEARS
⑭
TILTING BOX
A-END
V-AS1
V-AS2
B-END
DRIVE SHAFT
LOW
AUTO.
LOCAL
HAND
MAN.
HIGH
TO HANDWHEELS
B-END RESPONSE
HANDWHEEL DRIVE ASSEMBLY

83.86(53C)

Figure 6-9. — A-end control unit.

within predetermined limits of train before the positive stops are reached. Its operation is the same in all methods of power control.

The limit stop mechanism consists of a nut traveling on a threaded shaft (4), between two adjustable stops (5 and 6).

The threaded shaft is geared through an idler with gear 1 and rotates with it. When the traveling nut is driven into one of the limit stops, it jams and prevents rotation of gear 1.

As the handwheels are rotated in hand control, the traveling nut moves toward one or the other of the stops. As the guns reach the predetermined limit of train, the traveling nut will contact the stop. Further rotation of the handwheels causes the spring relief on the clutch to slip. As before, gear 1 is prevented from rotating by the limit stop mechanism.

Since the guns are in motion at the instant the limit stop acts, the tilting box has a definite angle of tilt. Mechanical response is still being applied and is rotating gear 2 and the screw control shaft. As gear 1 is prevented from rotating, the screw control shaft is moved through it laterally. This movement of the shaft returns the tilting box to neutral and the guns to rest.

In both local and automatic control, the indicator regulator controls the tilting box. The hand control clutch is disengaged. B-end response, however, is still being applied to gear 2. As gear 2 and the screw control shaft rotate, gear 1 (with little appreciable resistance acting on it) will rotate and drive the traveling nut toward one of the limit stops. As the stop is reached, gear 1 is prevented from rotating further. The screw control shaft, which is being rotated by gear 2, is now forced to move through gear 1. This action will result in returning the tilting box to neutral.

In both local and automatic control, the main piston (connected to the tilting box) will be moved by the limit stop mechanism, regardless of the dictates of the hydraulic control system. Chambers of the main piston are relieved by relief valve V-IHP located in the regulator control valve block (fig. 6-6).

Coarse Control

In the discussion of automatic control, the gun order signal was considered as coming into a single synchro receiver (the fine control synchro). This synchro, working in conjunction with the differential cam assembly, controls the position of the fine pilot valve initiating regulator action to bring the mount into synchronization with gun order.

Remember however, that the fine control synchro is 36 speed and will apparently synchronize at any multiple of 10 degrees from the gun order signal. This could easily be the case when the gun is shifted to automatic when there is a large difference between gun order signal and gun position.

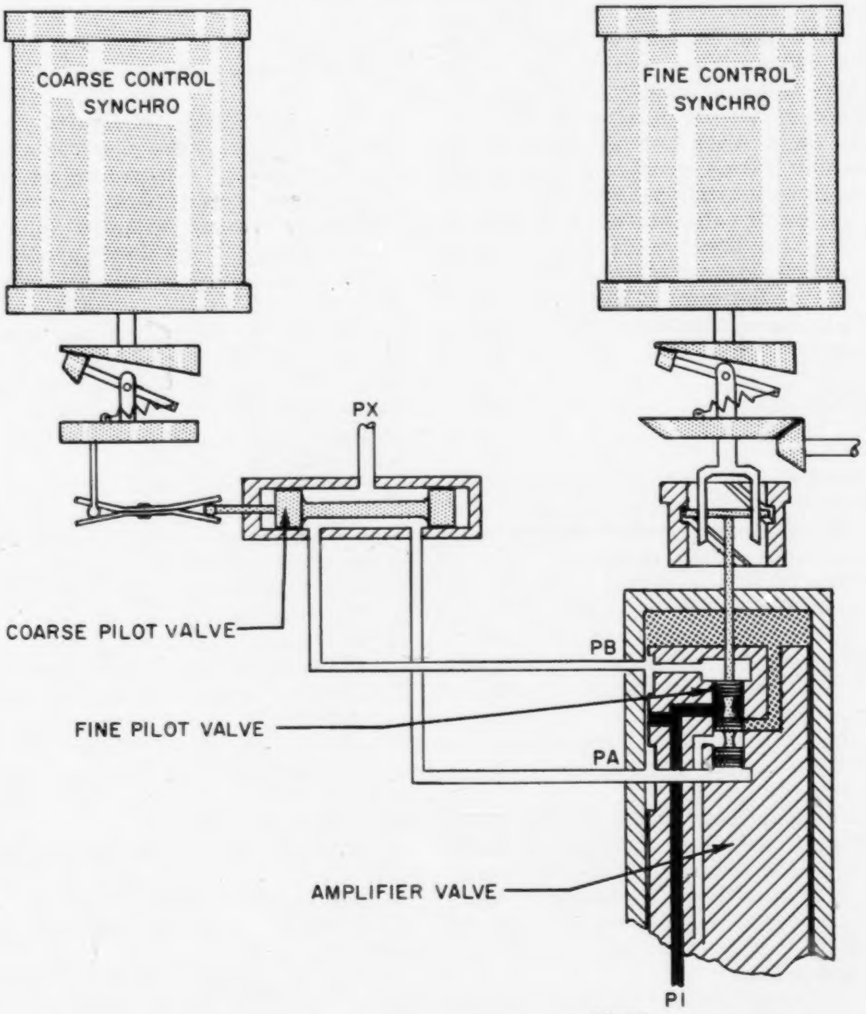
To prevent the mount from synchronizing 10° from the signal, another system called the coarse control system (fig. 6-10) is incorporated into the regulator. Essentially the system is composed of a 1-speed synchro and a coarse pilot valve.

The coarse control synchro receives the same gun order signal as the fine control synchro, but rotates at only 1 speed in train (2 speed in elevation). Rotation of its rotor positions the coarse pilot valve which is fastened to its output shaft. Mechanical response from the B-end is geared to the stator of the coarse control synchro and will rotate it an equal amount, but in the opposite direction. The rotating stator carries the rotor with it, so that response actuates the return of the rotor and the coarse pilot valve to its original position.

As shown in figure 6-10 the spaces above and below the fine pilot valve are vented to cavities in the sides of the amplifier piston and from there to the coarse pilot valve through two lines. Narrow grooves in the amplifier piston permit a small flow of oil from the P1 into this system. As long as the coarse pilot valve is at neutral, the chambers at either end of the fine pilot valve are connected to drain. This allows the fine pilot valve free movement for control of the mount.

Assume that a signal is received so as to move the fine pilot valve upward. When the error between gun order and gun response is approximately 2°, the fine pilot valve is displaced to the limits of its travel.

When the error reaches 3.8°, the coarse pilot valve will shift to the left, blocking PA to exhaust. With PA blocked to exhaust, PA would become the same pressure as P_1 and the fine pilot valve would be forced upward, in turn forcing the amplifier to move up to its extreme position. As a result, the guns will drive at maximum speed toward synchronization. As the error between gun order and gun position drops below 3.8°, the coarse pilot valve shifts to reopen PA to PX and the fine pilot valve resumes control.


COARSE CONTROL SYNCHRO
FINE CONTROL SYNCHRO
PX
COARSE PILOT VALVE
PB
FINE PILOT VALVE
PA
AMPLIFIER VALVE
PI

53.87
Figure 6-10.—Coarse control system.

Overtravel Due to a Change in Signal

As there is an inertia lag inherent in the design of the control equipment, the control valves go through a series of diminishing oscillating or hunting movements between the beginning and end of their response to a signal.

Mechanical response acts as soon as rotation of the B-end starts. When the guns have caught up with the signal, therefore, mechanical response has returned the fine pilot valve to neutral. At this point, however, gun velocity still exceeds the signal velocity, and the signal is overrun. Mechanical response then displaces the fine pilot valve below neutral causing control valves V-AM, V-AC, and V-M to be positioned in the opposite direction from their original displacements. The main piston, response piston, and the tilting box return part way toward neutral decelerating the guns. This signal now catches up with gun position; but, as the guns are decelerating, the signal overruns and again leads the guns. This slowing of mechanical response permits the signal to again raise the fine pilot valve above neutral, but for a shorter distance than originally. Thus the ensuing repetition of the original cycle of valve movements is on a smaller scale because the guns have become nearly synchronized with the signal as a result of the original action.

Identical cycles of valve movements continue with diminishing amplitude until gun position, velocity, and acceleration are synchronized with the same values of the signal. With your equipment in good operating condition, the maximum number of overtravel cycles will be three.

Synchronizing Control Device

This device functions only in automatic control. Its purpose is to bring the guns into synchronization with gun order rapidly and smoothly when the existing error exceeds 1.5 degrees. Errors of this magnitude are usually encountered when the mount is shifted to automatic control. After gun order and gun position agree, the error should not again become great enough for further action of the synchronizing control device.

This device will operate regardless of whether or not the coarse pilot valve has taken control of the fine pilot piston.

The synchronizing control device discussed here is used only with the Ford power drive found on twin 5"/38 mounts. It is not representative of the synchronizing devices found on other guns. For this reason, we will discuss only its function, rather than details of construction and operation.

The synchronizing control device gearing will operate to rotate the fine and coarse control synchro stators in such a way as to cause their pilot valves to move toward neutral.

The first output of the synchronizing control device furnishes an apparent response which will cause the fine pilot valve to take control of the equipment when the error is reduced to about one-half of its original value.

The synchronizing device then reverses its rotation so that its second phase produces an apparent signal. The regulator follows this apparent signal in fine control.

As a result of the two outputs of the synchronizing control device, the period of high acceleration is shortened, gun overtravel is reduced, and the guns and signal are synchronized smoothly and quickly.

Synchro Power Failure Device

The synchro power failure device (fig. 6-11) operates to bring the mount to a standstill in the event of loss of synchro supply. The three main components of this device are (1) a solenoid (energized by the synchro supply circuit), (2) a friction brake, and (3) the synchro power failure valve. The valve and friction brake are attached to a vertical, axially movable shaft. The spring-loaded shaft is normally held in its down position by the action of the solenoid and lock arm when the equipment is in automatic control. In other types of control the shaft is held down (and inoperative) by action of the cam on a roller of the latch arm.

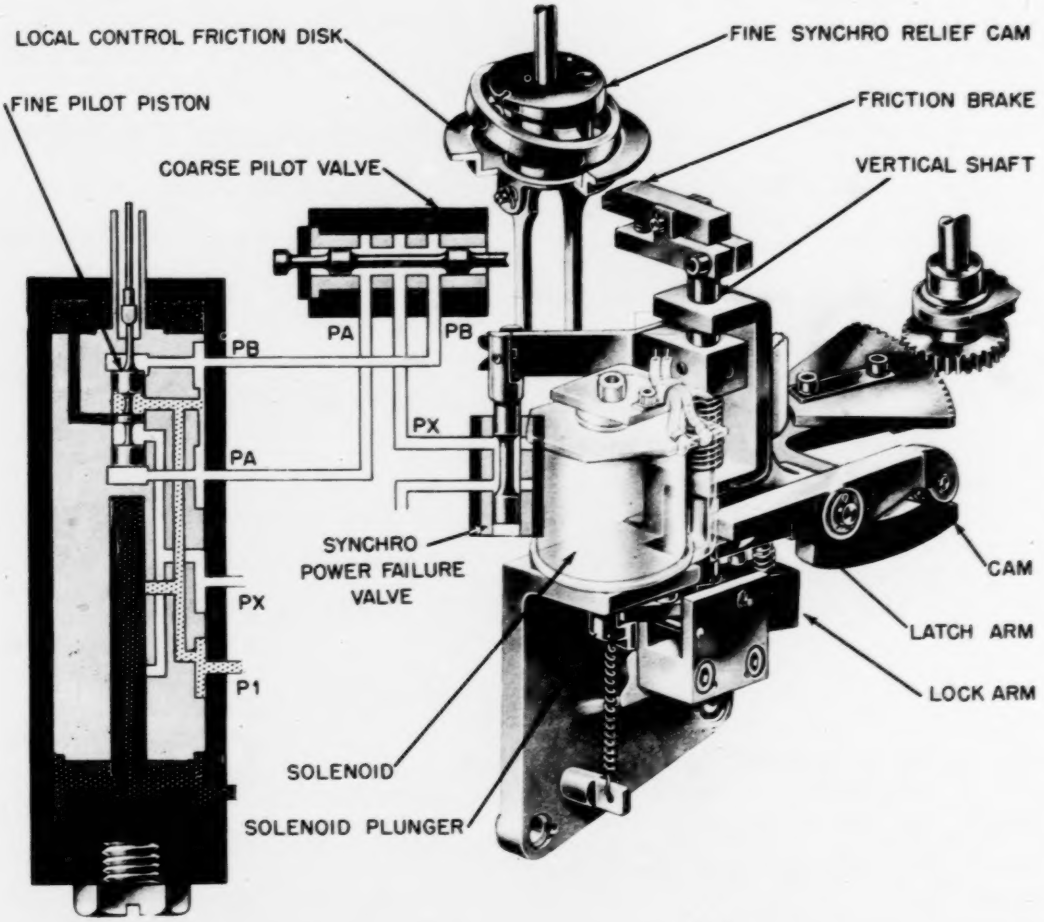
When synchro supply fails, the solenoid acts to trigger the release of the spring-loaded shaft. The cork-faced brake surface then comes into contact with the local control friction disc, arresting further rotation of the fine synchro fork.

To prevent the coarse pilot valve, now uncontrollable, from blocking either PA or PB and thus keeping the fine pilot valve fully displaced, the synchro power failure valve pulls up, closing PA and PB to PX. The pressures at both ends of the fine pilot valve become equal through the connecting ports of P1. Mechanical response, rotating the differential cam, returns the fine pilot valve to neutral.

So far we have discussed the control equipment used with the 5"/38 gun system. In the next section of this chapter we will explain the hydraulic control equipment used with the 5"/54 gun system.

The 5"/54 Gun Mount Mk 42 was developed as an AA gun to be used against high speed jet aircraft. It has proven to be a reliable and efficient weapon system. There are now nine modifications (Mods) of the 5"/54 Gun Mount Mk 42. The power drives and control equipment used with Mods 1 through 8 are basically the same. However, the Mod 9 resulted in major changes in control circuits, receiver regulators, and electronic servo control units (servoamplifier). For this reason, we will explain the 5"/54 hydraulic control equipment in two sections, that used to control Mods 1 through 8 and that used with Mod 9.

To obtain better control and faster response to gun order signals, a new type of receiver-regulator was developed for the 5"/54 gun system.


LOCAL CONTROL FRICTION DISK
FINE SYNCHRO RELIEF CAM
FINE PILOT PISTON
FRICTION BRAKE
COARSE PILOT VALVE
VERTICAL SHAFT
PA
PB
PB
PX
PA
SYNCHRO POWER FAILURE VALVE
CAM
PX
LATCH ARM
P1
LOCK ARM
SOLENOID
SOLENOID PLUNGER

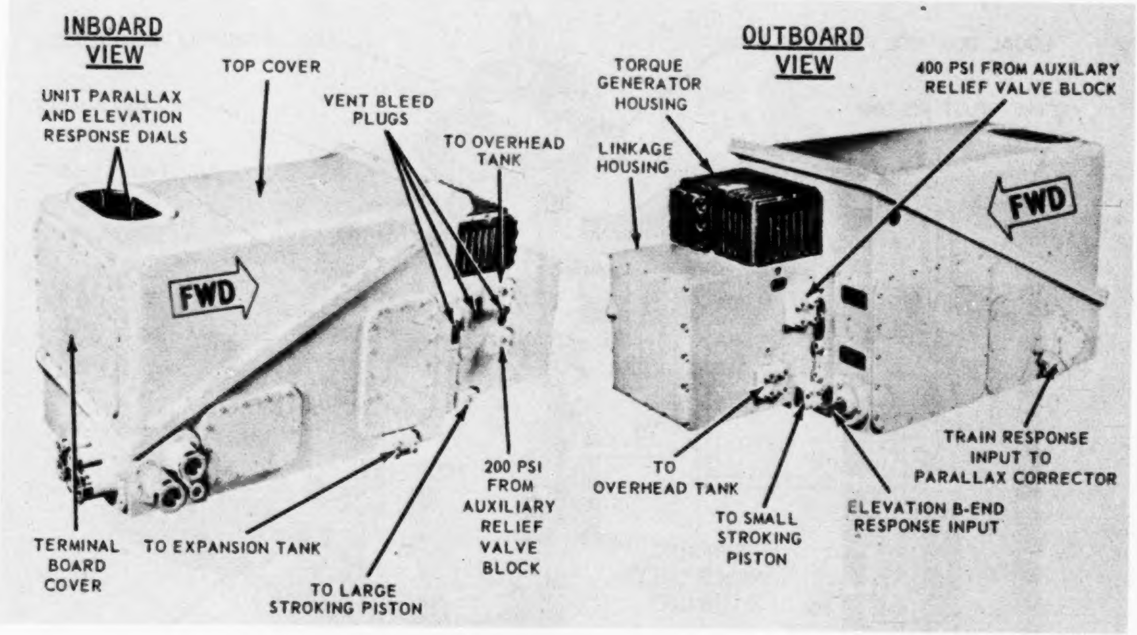
53.88
Figure 6-11.—Synchro power failure device.

It is a major element of the hydraulic control system and is similar in purpose to the indicator-regulator you studied on 5"/38 control equipment, but it differs considerably in component details. These differences will be readily apparent to you as we go along with the study of the receiver-regulator and its associated equipment for control of the 5"/54 hydraulic power drive.

RECEIVER-REGULATOR

As there is basically little difference between the train and elevation receiver-regulators used with the 5"/54 Mods 1 through 8, we will study only the elevation one here. The elevation receiver-regulator consists of electrical, hydraulic, and mechanical components arranged in (and on) a regulator housing, figure 6-12. The receiver-regulator system is arranged so that it can control the drive in response to electrical gun elevation order signals from either remote or local sources as determined by the position of selector switches of the control devices.

In remote control, the gun elevation order is applied as a synchro signal from a remote director, plotting room, or to the receiver of the receiver-regulator. If the existing gun position is not in correspondence with the order, an error signal is generated in the receiver. This


INBOARD VIEW
UNIT PARALLAX AND ELEVATION RESPONSE DIALS
TOP COVER
VENT BLEED PLUGS
TO OVERHEAD TANK
FWD
TERMINAL BOARD COVER
TO EXPANSION TANK
TO LARGE STROKING PISTON
200 PSI FROM AUXILIARY RELIEF VALVE BLOCK
OUTBOARD VIEW
TORQUE GENERATOR HOUSING
LINKAGE HOUSING
400 PSI FROM AUXILARY RELIEF VALVE BLOCK
FWD
TO OVERHEAD TANK
TO SMALL STROKING PISTON
ELEVATION B-END RESPONSE INPUT
TRAIN RESPONSE INPUT TO PARALLAX CORRECTOR

53.220
Figure 6-12. — Elevation receiver-regulator Mk 20 Mods 1-17.

error signal, after amplification in the regulator amplifier, is applied to the regulator which automatically regulates the drive to bring the gun into correspondence with the order as quickly as possible within preset maximum velocity and acceleration limits.

In addition to the gun elevation orders, a parallax correction order is received as a synchro signal from the fire control system. This signal results in the generation of a parallax error signal which, after amplification in the parallax correction amplifier, alters the gun elevation order by the required amount. It should be noted that only unit base parallax signals are transmitted. Each mount signal is further modified as required by its particular position from the director through the use of mechanical change gears within the parallax mechanism.

In local control, the gun elevation order is originated by manipulation of the one-man control units in the local control stations.

The receiver-regulator has three operational parts or circuits. These are: the primary controller, the secondary controller, and the integrating system. Let's take a look at these parts separately to see what each does in controlling the power drive.

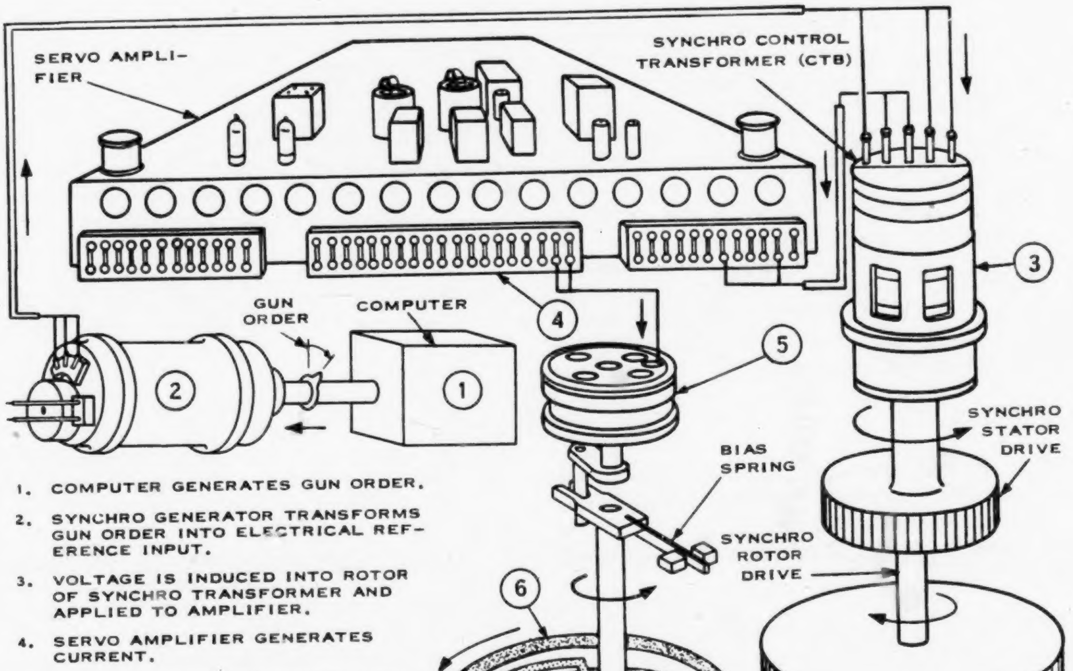
PRIMARY CONTROLLER

The purpose of the primary controller is to generate an angular rotation which is proportional to the difference (error) between gun elevation and the gun order angle in degrees. This rotation is a measure of the error signal and is called the actuating signal. The actuating signal is used to actuate the valves and pistons in the regulator by means of the PE1 cam.

The principal components of the elevation primary controller are: the elevation synchro system, the servoamplifier, d-c torque generator, VE1 rotary valve, PE1 rotary piston, and VE3 pressure divider valve. These units are connected together as shown in figure 6-13.

Elevation Synchro System

The elevation synchro system is a typical control synchro system as described in chapter 2. A one-speed synchro control transformer


SERVO AMPLIFIER
SYNCHRO CONTROL TRANSFORMER (CTB)
GUN ORDER
COMPUTER
1
2
3
4
5
6
7
8
BIAS SPRING
SYNCHRO STATOR DRIVE
SYNCHRO ROTOR DRIVE
VE1
PE1
VE3
P1
T
PE1 CAM

1. COMPUTER GENERATES GUN ORDER.
2. SYNCHRO GENERATOR TRANSFORMS GUN ORDER INTO ELECTRICAL REFERENCE INPUT.
3. VOLTAGE IS INDUCED INTO ROTOR OF SYNCHRO TRANSFORMER AND APPLIED TO AMPLIFIER.
4. SERVO AMPLIFIER GENERATES CURRENT.
5. TORQUE GENERATOR TWISTS VE1.
6. OIL FLOWS FROM VE1 INTO PE1.
7. ROTATION OF PE1 IS GEARED TO ROTOR OF SYNCHRO TRANSFORMER. ROTOR TURNS IN DIRECTION TO REDUCE INDUCED VOLTAGE.
8. PE1 CAM TURNS WITH PE1. ROTATION IS PROPORTIONAL TO ERROR BETWEEN GUN ORDER AND GUN ELEVATION.

▦ = P1 PRESSURE (400 PSI) (RED)
░ = TANK (0 PSI) (YELLOW)
▒ = VARYING PRESSURES (GREEN)
■ = 0 TO 200 PSI (BLUE)

53.221
Figure 6-13.—Elevation regulator primary controller.

is provided for getting the gun within 2-1/2 degrees of correspondence with gun order. A 36-speed synchro control transformer normally controls the gun at all times, except when shifting directors or from local to remote control.

The synchro control transformer receives the gun order signal from a synchro generator, compares it with actual gun position, and generates a voltage that is proportional to the difference between gun order and gun position. The voltage thus generated is applied to the servoamplifier where it is amplified and changed from alternating voltage to direct current. This current is then used to drive the d-c torque generator which positions VE1 rotary valve to initiate movement of the gun.

Servoamplifier

The train and elevation servoamplifiers are both mounted in a single chassis (fig. 6-14). A second chassis mounts the power supply for each of them. Each servoamplifier has four main sections:

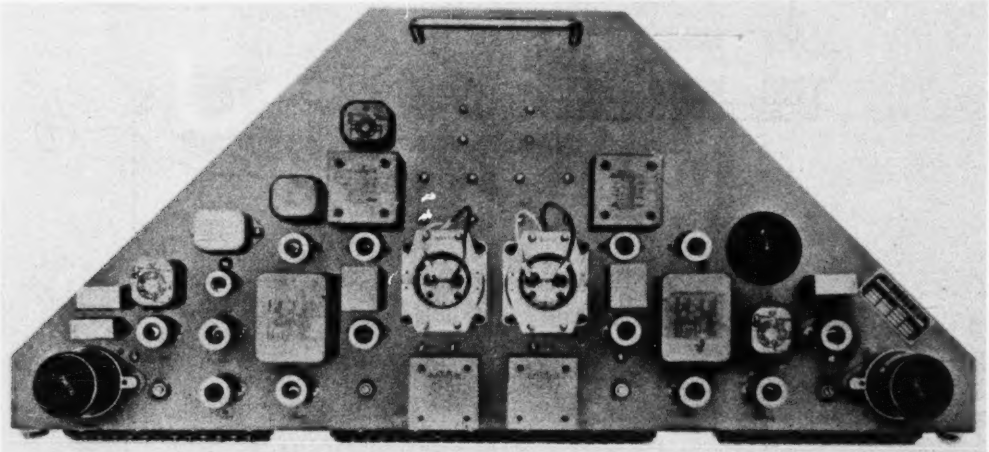
1. The synchro changeover unit
2. The a-c amplifier
3. The demodulator
4. The d-c amplifier

The only purpose of the synchro changeover unit is to switch the input to the amplifier from the 36-speed synchro to the one-speed synchro whenever the mount is more than 2-1/2 degrees out of synchronization. Remember, the gun is, normally, always under control of the 36-speed synchro except when being shifted to a new director or from local to remote control. The error signal, whether from the one-speed or the 36-speed synchro, passes through the synchro changeover unit and into the a-c amplifier.

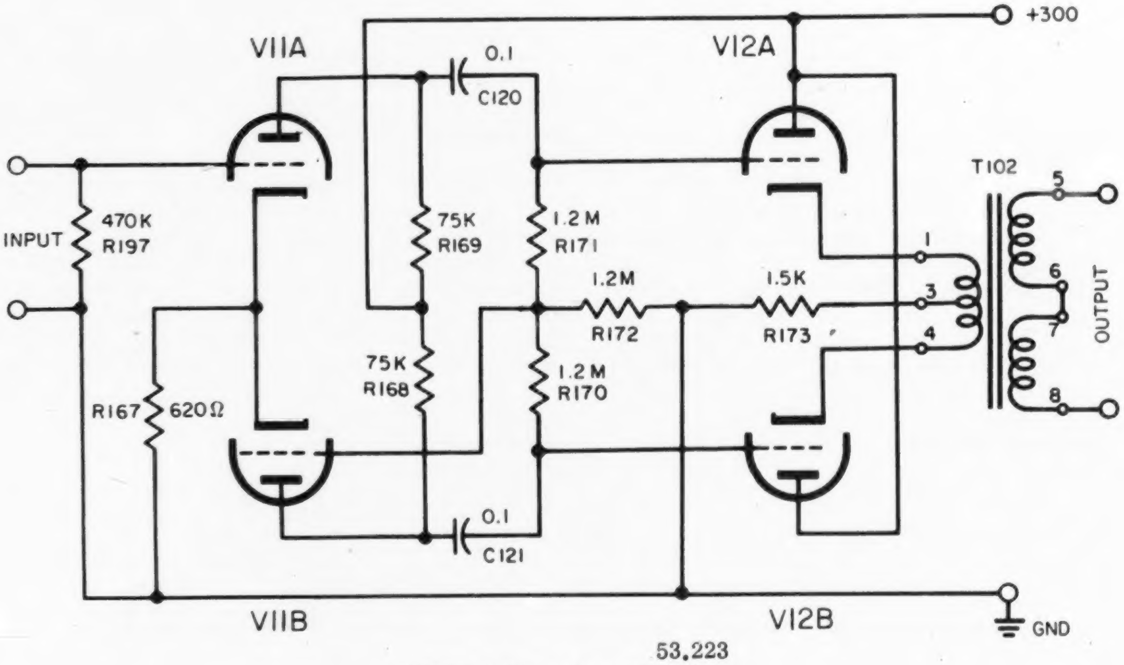
The purpose of the a-c amplifier is to amplify the output from the synchro changeover unit (the error signal). The a-c amplifier consists of vacuum tubes V11 and V12, transformer T102, and associated circuit components (fig. 6-15).

Vacuum tube V11 functions as a voltage amplifier and phase inverter. A phase inverter converts a single-ended input to a push-pull output. Tube V12 is a cathode-follower power (current) amplifier. The transformer (T-102) acts as a coupling device (input) to the next stage (demodulator).

Push-pull amplifiers require two signal voltages of equal magnitude but 180 degrees out of phase for proper operation. The input signal appears across R197 to the grid of V11A. The purpose of R197 is to develop an incoming signal and provide a d-c return path to ground potential from the grid of V11A. V11A performs two functions: it provides an amplified a-c signal at its plate which is coupled to the grid of V12A through d-c blocking capacitor C120, and it



53.222
Figure 6-14.—Train and elevation servoamplifiers, top view.



53.223
Figure 6-15.—A-c amplifier.

provides an a-c signal which drives V11B. Since the grid of V11B is connected at the junction of R171 and R172 which develop a signal voltage for the grid of V12A, a portion of the signal voltage is also applied to the grid of V11B. After being amplified by V11B, the signal is coupled through d-c blocking capacitor C121 and appears across resistors R170 and R172 as the signal to the grid of V12B. The resistance of R171 and R172 is so chosen that the size of the signal applied to V11B is the same as that of the signal applied to V11A.

Because there is always a 180 degree phase shift between the signal on the grid and the signal on the plate of an amplifier tube, the signal appearing at the grid of V11B is 180 degrees (inverted) out of phase with the signal appearing at the grid of V11A. Thus, if a positive-going signal is applied to V11A, a negative-going signal will be applied to V11B and the grids of V12A and V12B will receive equal but opposite phase signals. These two signals together are called a push-pull signal.

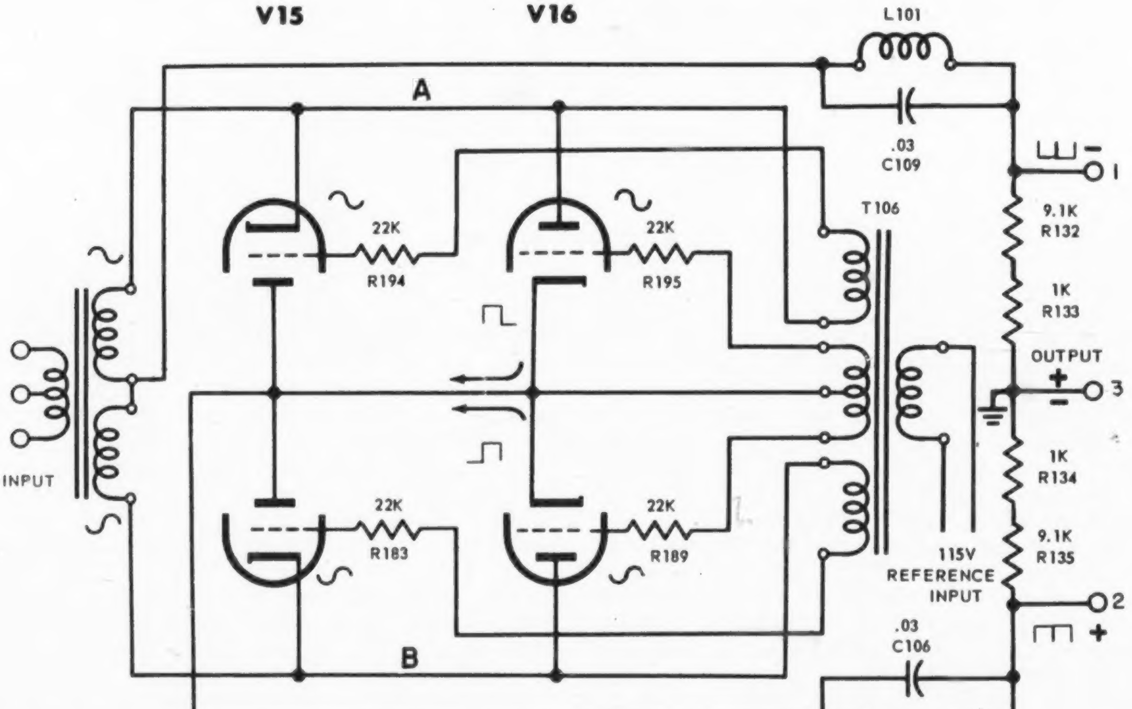
The push-pull signal from V11A and V11B is of the proper voltage value to operate the next stage but cannot supply enough current. V12A and V12B are cathode-follower power amplifier tubes, (the output is taken from the cathode rather than the plate). These tubes supply sufficient current for the following stage but do not amplify the voltage.

The V12 circuit is called a push-pull stage because an increasing current flow occurs in one tube section at the same time as a decreasing current flow occurs in the opposite tube section.

The cathode of each tube section is connected to opposite end taps of a center tapped transformer's primary windings (T102). Therefore, when the grid of V12A becomes more positive, it causes an increase in current flow through the upper half (terminals 1 and 3) of transformer T102 (fig. 6-15). At the same time, the grid of V12B becomes more negative and causes a decrease in current flow through the lower half of transformer T102 (windings 3 and 4). With one half of the primary windings going negative and the other half going positive, the out of phase currents set up in the primary (windings 1, 3 and 4) of the transformer produce in the secondary an a-c signal equal to the sum of the two currents. A half-cycle later, the current flow through the transformer reverses and an opposite phase signal is produced The amplified error signal from the secondary of transformer T102 is the input to the next stage of the servo amplifier, the demodulator.

The demodulator circuit shown in figure 6-16 converts the a-c error signal into a pulsating d-c error signal whose amplitude is varied in accordance with the strength of the a-c error signal. The demodulator also discriminates between an increasing error (right train or elevation) signal by having the output polarity change when the order signal changes. For example, if the output across the demodulator load (shown as R132, R133, R134 and R135) is polarized as shown in figure 6-16 for an increasing order signal, the polarity across the load will reverse when a decreasing order signal is applied.

The demodulator receives the amplified error signal from the a-c amplifier via transformer T102. Besides the signal voltage, the demodulator also receives another a-c voltage, called the reference input. This 115VAC reference input is applied across the primary of transformer T106 (fig. 6-16) and is the same voltage used as reference for synchro supply. Since the same voltage source is utilized for both the error signal and the reference input, the phase angle between them is always zero. That is, both are alternating voltages whose magnitudes must pass through zero at the same instant regardless of the signal, that is either a positive for one half cycle of the source and a negative for the other half cycle of the source. The reference input phase polarity always remains constant for either half cycle, while the signal input polarity depends upon the direction of movement of the controlling station.



53.224
Figure 6-16.—Demodulator.

There are four secondaries to T106 which are connected to the grid and cathode of the four triode sections of tubes V15 and V16. Each triode section acts like a diode that can conduct only when grid and plate are positive in respect to the cathode. The circuit for each tube is arranged in such a manner that only one of the triode sections can pass current for a given condition. V15 is utilized only when the signal input and reference input are out of phase with each other. Under this condition, one triode of V15 functions during a positive going signal input and the other triode functions during a negative going signal input. V16 is utilized only when the signal input and reference input are in phase. The triode sections of V16 depend on the half cycle inputs in the same manner as V15.

The load of the demodulator circuit consists of inductor L101, capacitors C109 and C106, and resistors R132, 133, 134 and 135. The purpose of L101, C106, and C109 is to filter most of the pulsations which would otherwise occur in the current from the demodulator. The important points to remember are that the reference input phase polarity does not change in relation to the source and that the signal voltage polarity depends on the direction ordered by the controlling station. Also remember that the output voltage phase changes only when the signal input phase and reference input phase change in relation to each other due to a change in direction of the order signal.

The output from the demodulator is amplified at the d-c amplifier. The d-c amplifier consists of vacuum tubes V13 and V14 and associated circuit components. Figure 6-17 is a schematic diagram of the d-c amplifier.

V13 is a cathode follower type tube, much like V12 in the a-c amplifier. It amplifies the signal from the demodulator to the grids of V14. V14 is the principal output power amplifier tube in the d-c amplifier. R185 is a d-c balancing potentiometer. It is adjusted so that equal currents flow through the two sections of V14 when there is no input signal. R211 and R212 are in the grid leads of V14. They are current limiting resistors to prevent excessive current from flowing in the grids of V14. C134 and C135 are connected from the grids to the cathode of V14. They suppress very high frequency oscillations which might otherwise occur in V14. R187 develops a positive cathode bias for V14 due to plate current through R187.

The plate currents in V14 vary in proportion to the voltages applied to the grids. These currents are applied to the torque generator. C124 and C125, R181 and R182 in the plate circuits of V14 are filters for preventing sudden changes in the current to the torque generator.

The d-c amplifier also receives two additional inputs:

A dither signal from the 6.3V 60 cycle filament supply is induced via transformer T103 to the grid circuit of tube V14. This voltage is taken from the 6.3V filament supply by way of a variable attenuator consisting of resistors R174 and R180, figure 6-17.

Dithering the hydraulic system consists of shaking the hydraulic valves at a high rate and small amplitude to prevent them from sticking in their sleeves. To accomplish this, they are vibrated to a 60 cycle per second rate by coupling an alternating voltage to the grid circuit of tube V14 by means of transformer T103.

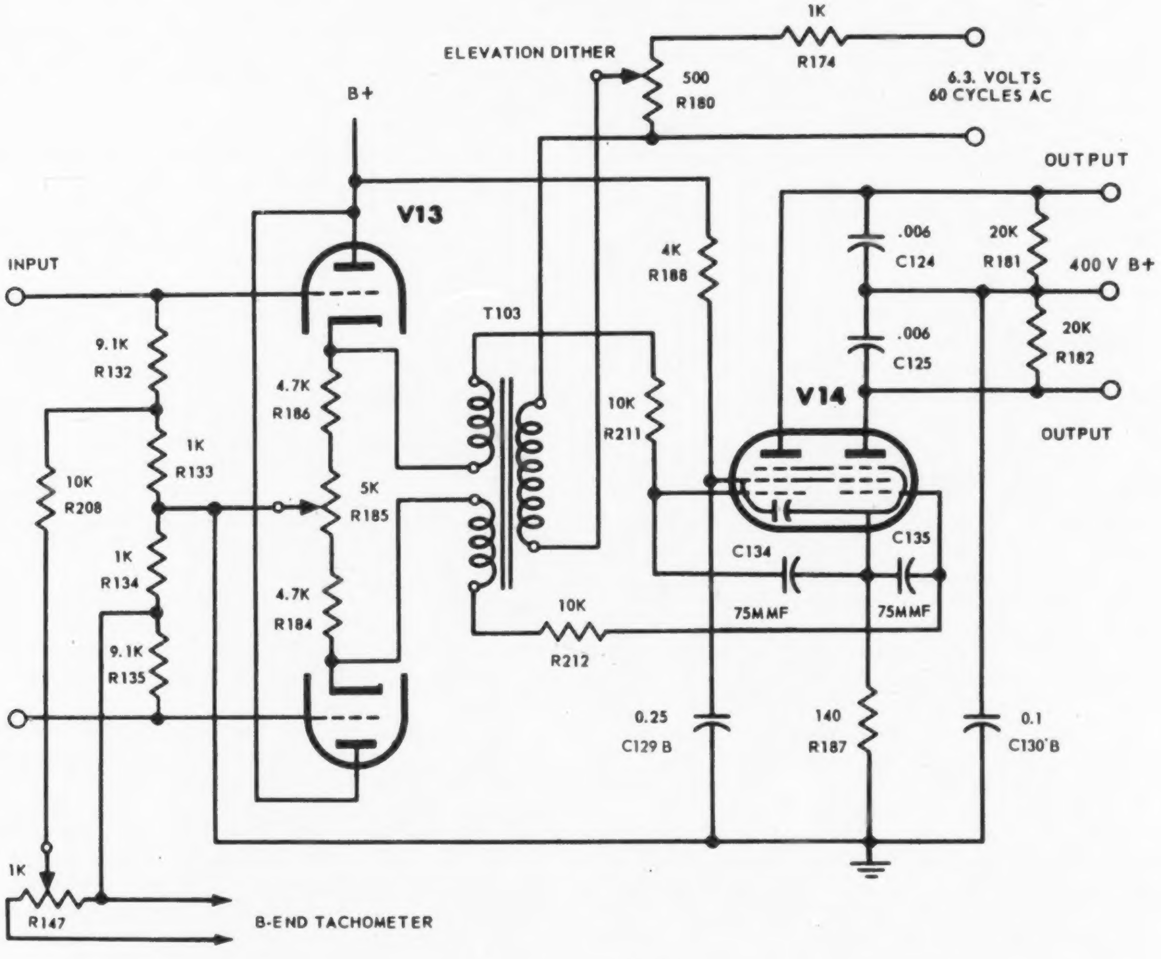
Another signal is received from the B-end tachometer which is geared to the B-end hydraulic transmission. This signal is proportional to B-end speed and is coupled to the signal input to vacuum tube V13 by way of an attenuator consisting of R147 and R208, figure 6-17. This B-end velocity feedback signal reduces the B-end error when the gun is following roll order signals.

In summing up the four sections of a servo-amplifier, a signal input from a computer was compared with gun position by the control synchro system, the resulting error signal was amplified by the a-c amplifier, and changed from a-c to d-c in the demodulator. This d-c signal is then amplified by the d-c amplifier and applied to the torque generator. The torque generator, in response to this applied current, rotates the rotary valve VE1 to actuate the hydraulic power drive.

Torque Generator

The torque generator generates a rotating force which is proportional to the direct current applied from the d-c amplifier. This rotation acts against a bias spring. The greater the force of rotation, the farther the spring can be bent and the rotary valve, VE1, being attached to the rotor of the torque generator, is turned proportionally, (fig. 6-13).

Figure 6-18 is a schematic diagram of the torque generator. It consists of an iron rotor and four field windings on an iron stator. Current from one side of tube V14 in the d-c amplifier flows through the windings on poles 1 and 3.


ELEVATION DITHER
1K
R174
500
R180
6.3. VOLTS
60 CYCLES AC
B+
OUTPUT
V13
.006
C124
20K
R181
400 V B+
INPUT
4K
R188
T103
.006
C125
20K
R182
9.1K
R132
4.7K
R186
10K
R211
V14
OUTPUT
1K
R133
10K
R208
5K
R185
C134
C135
1K
R134
4.7K
R184
10K
R212
75MMF
75MMF
9.1K
R135
0.25
C129 B
140
R187
0.1
C130 B
1K
R147
B-END TACHOMETER

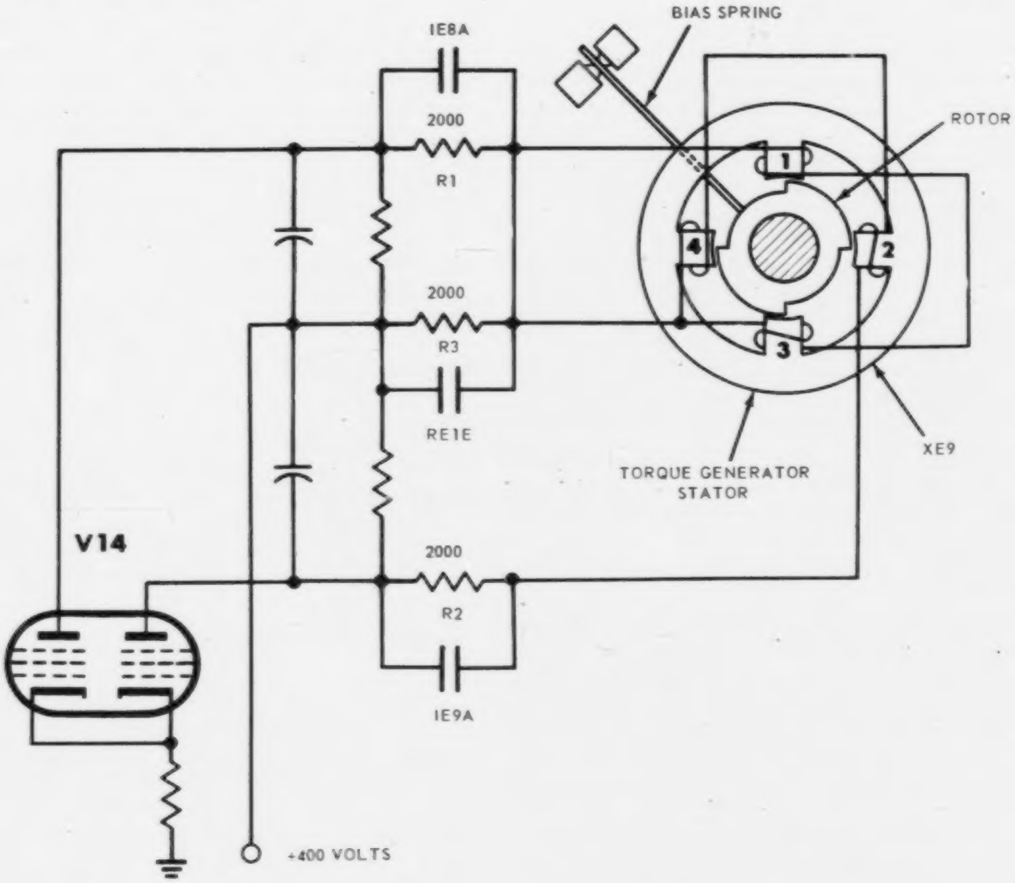
53.225
Figure 6-17.—D-c amplifier.

Current from the other side flows through the windings on poles 2 and 4. When the current in one set of windings increases, the rotor tends to rotate in the direction which lines up with these windings. For instance, if the current in the windings on poles 1 and 3 increases, the rotor rotates counterclockwise; if the current in the windings on poles 2 and 4 increases, the rotor rotates clockwise against the bias spring.

Resistors R1, R2, and R3 protect the torque generator from burning out by limiting the current during synchronizing, starting, and periods of testing when the amplifier is energized and the transmission power motor is not running. Switches IE8A and IE9A are open when the rotary piston PE1 is at an extreme position. RE1E is open when the elevation transmission power motor is not running.

Rotary Valve VE1

The rotary valve, in conjunction with pressure dividing valve VE3, controls the movement of rotary piston PE1 and, consequently, cam PE1. Rotation of cam PE1 sets in motion the next



53.226

Figure 6-18.—D-c torque generator.

stage of operation in controlling the power drive—the secondary controller. But first, let's finish the action through the primary controller.

In figure 6-13 a counterclockwise rotation is being imparted to the rotor of the rotary valve from the torque generator. This will allow oil from line P1 to enter the valve and flow into the control line to one side of rotary piston PE1. The rate at which the oil flows is proportional to the angle through which the rotary valve is turned from neutral. This oil under pressure from the rotary valve causes rotary piston PE1 to rotate clockwise as indicated.

Should the rotary valve have been turned the other way, the control line to PE1 would be connected to tank pressure (0 psi) and oil would then flow away from PE1 causing its piston to rotate in a counterclockwise direction. PE1 is geared to the rotor of the synchro control transformer and drives the rotor in the direction which reduces the induced voltage in the rotor to zero. Then there is no input to either the servoamplifier or torque generator. VE1 is returned to neutral by the bias spring and PE1 stops in that position.

Referring back to figure 6-13, another oil line can be seen entering rotary piston PE1. This line is ported from pressure dividing valve VE3.

Pressure Dividing Valve VE3

The purpose of pressure dividing valve VE3 is to maintain a constant pressure of 200 psi on its side of the PE1 piston. When the rotary valve VE1 is in the neutral position, pressure line P1 is equally opened to the tank line and to the control line PE1. As P1 is always at 400 psi the pressure in the PE1 control line is then regulated at 200 psi, or at a pressure midway between the P1 pressure and tank pressure. Turning of the rotary valve in a clockwise direction closes off line P1 and opens the tank port. Pressure in the PE1 control line then drops below 200 psi. The 200-psi pressure from the pressure dividing valve will then cause the rotary piston to turn in a counterclockwise direction.

Turning of the rotary valve in a counterclockwise direction opens line P1 while closing off the tank port. Pressure in the PE1 control line then increases to above 200 psi and the rotary piston will be turned in a clockwise direction.

The operation of pressure dividing valve VE3 is controlled by the areas of the top and bottom lands of the valve. Figure 6-13 shows the end of the plunger extending from the left end of VE3 sleeve. This extended portion of the plunger leaves exactly one-half as much operating area exposed to oil pressure on the left-hand side of the valve plunger as on the right-hand side. With P1 pressure at 400 psi ported to the left-hand side, a pressure of but 200 PSI is required to balance the valve because of the difference in operating, or working, area between the two ends of the valve plunger. Any change in pressure in the right-hand side of the valve will result in an unbalance and the plunger will move.

Let's look again at the diagram of VE3 in figure 6-13. Besides P1 to the left-hand side of the valve, three other oil lines lead into the valve. One line is to the tank, one is to the PE1 rotary piston, and the other is P1 pressure. With the VE3 plunger in the neutral position, the lines to the tank and to the right-hand P1 are equally cracked to the pressure dividing chamber, maintaining the pressure there and in the line to the PE1 rotary piston at 200 psi. With the rotary valve VE1 on neutral, 200 psi will also be acting on the other side of rotary piston PE1, and PE1 will not move.

Should VE1 rotate away from neutral in a counterclockwise direction, pressure in its line to PE1 will be increased to over 200 psi. With but 200 psi acting on its other side, the PE1 rotary piston will move in a clockwise direction, thus increasing the pressure in the line to VE3. The VE3 plunger will then move to the left, opening the port to the tank in an attempt to restore and maintain the 200 psi in its side of the PE1 line.

This action will be just the opposite should VE1 move in the other direction. With pressure in the line to PE1 dropping below 200 PSI, the PE1 piston will move in a counterclockwise direction. As the pressure in the VE3 side drops with the PE1 piston moving away, the VE3 plunger will move to the right, again restoring the 200 psi by opening the right side of the valve chamber momentarily to the P1 line.

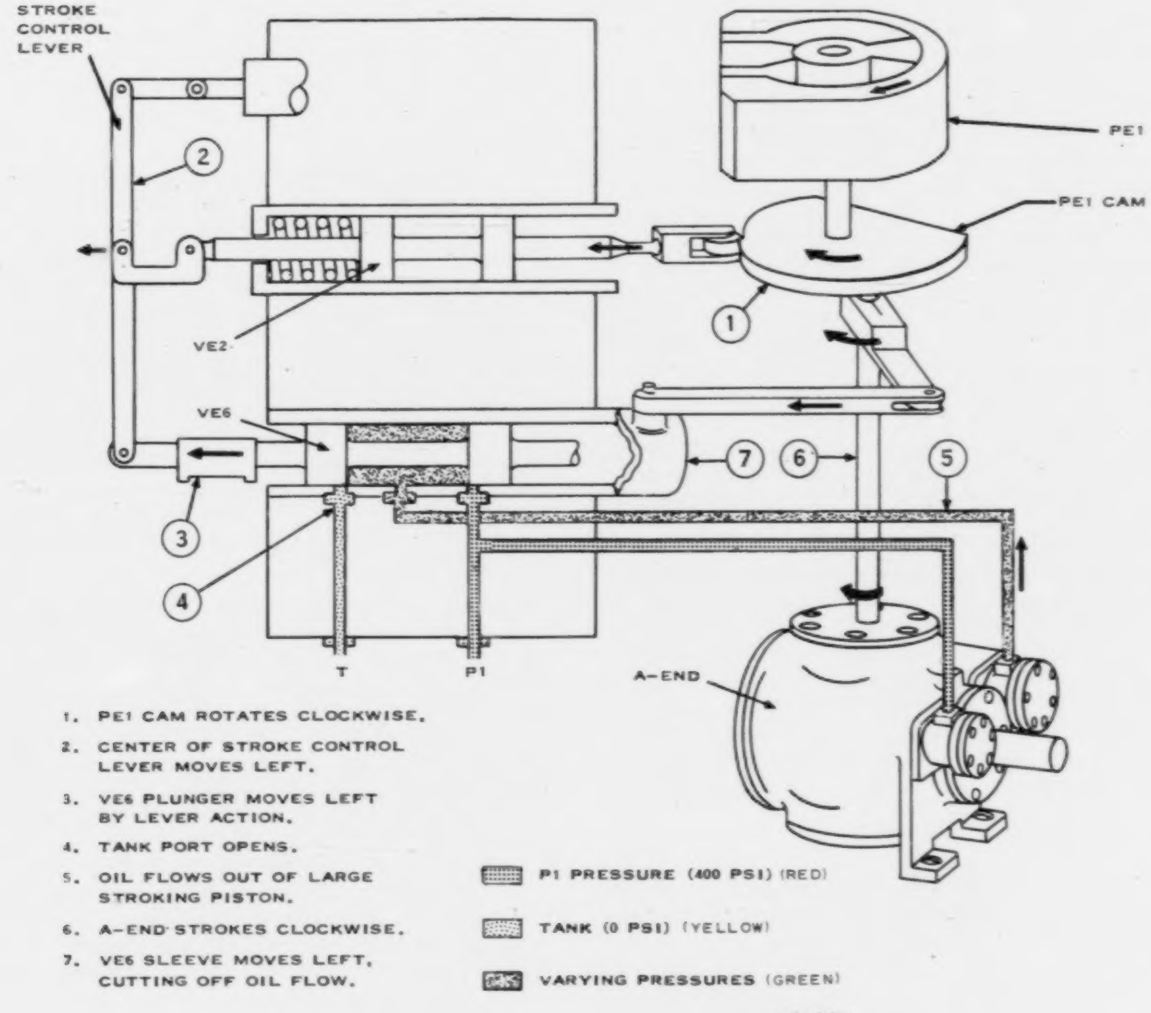
The movement of VE3 plunger is proportional to the rate of oil flow from VE1. The rotation of PE1 piston from neutral is also proportional to the amount of oil flow from VE1. Therefore, the movement of the VE3 plunger is proportional to the speed of rotation of the PE1 piston.

SECONDARY CONTROLLER

The purpose of the elevation secondary controller is to stroke the A-end of the hydraulic transmission by means of the stroking pistons. It consists of the VE6 valve, transmission stroking pistons, and connecting linkage as shown in figure 6-19. The stroking pistons are of unequal size; the smaller having exactly one-half the working area of the larger one. Movement of the stroking pistons is controlled by the VE6 valve.

In figure 6-19 action of the primary controller is rotating the PE1 rotary piston in a clockwise direction. The PE1 cam, being directly connected to the PE1 rotary piston, is rotating with it. Camming action, thrusting through valve VE2, drives the center of the stroke control lever to the left. Note: Valve VE2 performs no hydraulic function under normal control. Its function is to neutralize and hold rotary piston PE1 when the B-end brake is set, or in case of power failure. For the time being, consider the top end of the stroke control lever as fixed. When the PE1 cam drives the center of this lever to the left, the bottom end of the lever is driven to the left, pulling VE6 plunger to the left.

Referring again to figure 6-19 you will note three oil lines entering valve VE6. One is a



1. PE1 CAM ROTATES CLOCKWISE.
2. CENTER OF STROKE CONTROL LEVER MOVES LEFT.
3. VE6 PLUNGER MOVES LEFT BY LEVER ACTION.
4. TANK PORT OPENS.
5. OIL FLOWS OUT OF LARGE STROKING PISTON.
6. A-END STROKES CLOCKWISE.
7. VE6 SLEEVE MOVES LEFT, CUTTING OFF OIL FLOW.

▦ P1 PRESSURE (400 PSI) (RED)

░ TANK (0 PSI) (YELLOW)

▨ VARYING PRESSURES (GREEN)

53.227

Figure 6-19.—Schematic of secondary controller.

pressure relief, or drain, line to the tank. The one to the right is P1 pressure at 400 psi. P1 pressure also leads directly to the smaller of the two stroking pistons. The other line leads from valve VE6 to the larger of the stroking pistons. You will also note that both the valve plunger and valve sleeve of VE6 can be moved in relation to each other. When the plunger and sleeve are neutralized or at the zero position with each other, the pressure in the central chamber of VE6, and in the line to the large stroking piston, is at 200 psi. This is because the ports to the P1 pressure line and to the tank are equally cracked to the valve central chamber. With the large stroking piston having exactly twice the working area of the small one, this 200 psi will balance the 400 psi acting on the small piston, and the A-end tilt plate will remain on neutral.

With the valve plunger being pulled to the left by the stroke control lever, as in figure 6-19, the P1 port is closed off and the tank port opened. As a result, oil will flow from the central chamber of VE6 and, from the line to the large stroking piston, to the tank. P1 pressure on the small stroking piston will then rotate the A-end tilt plate clockwise moving the large stroking piston outward.

The A-end tilt plate is coupled at its pivot point to the movable sleeve of VE6 as shown in figure 6-19. As the tilt plate rotates, the VE6 sleeve is moved to the left until P1 is opened and the tank port closed off sufficiently to restore the pressure in the central chamber to 200 psi, thus balancing the force in the large and small stroking pistons. Since the VE6 sleeve follows the motion of the VE6 plunger, the A-end tilt plate rotation will be proportional to the movement of the VE6 end of the stroke control lever.

Working in conjunction, the primary and secondary controllers thus stroke the A-end of the hydraulic transmission. The A-end in turn pumps oil to the B-end causing it to rotate at a speed and in a direction proportional to the angle and direction of tilt of the A-end tilt plate. Since the gun is geared to the B-end, it elevates or depresses according to the rotation of the B-end. The B-end response shafting and gearing couples the rotation of the B-end to the stator of the synchro control transformer in the receiver-regulator. Thus the stator of the synchro control transformer is rotated proportional to rotation of the B-end, taking off the error signal as it is answered by mount movement.

INTEGRATING SYSTEM

We said before that the primary controller generates the actuating signal which is a measure of the error between the actual gun elevation and the gun order signal. The purpose of the integrating system is to reduce this error quickly by adding to the stroke of VE6. It does this by stroking the opposite end of the stroke control lever in such a way that it aids the stroking of VE6 by the primary controller.

Figure 6-20 is a schematic drawing of the integrating system. It is made up of VE7 valve, PE8 piston, VE8 valve, and PE7 piston. Oil is supplied to the system from the P2 pressure supply at a constant 200 psi.

The three parts of figure 6-21 show how the integrating system adds to the stroke of VE6 to reduce the elevation error more quickly. Part A shows all the elements in the neutral position with no actuating signal. Part B shows a large actuating signal acting on the stroke control lever to stroke valve VE6. In this illustration, integrating is purposely omitted. PE7 remains stationary and the left-hand end of the stroke control lever remains a fixed pivot. Under this condition, a large actuating signal is required from the PE1 cam to stroke valve VE6 as shown.

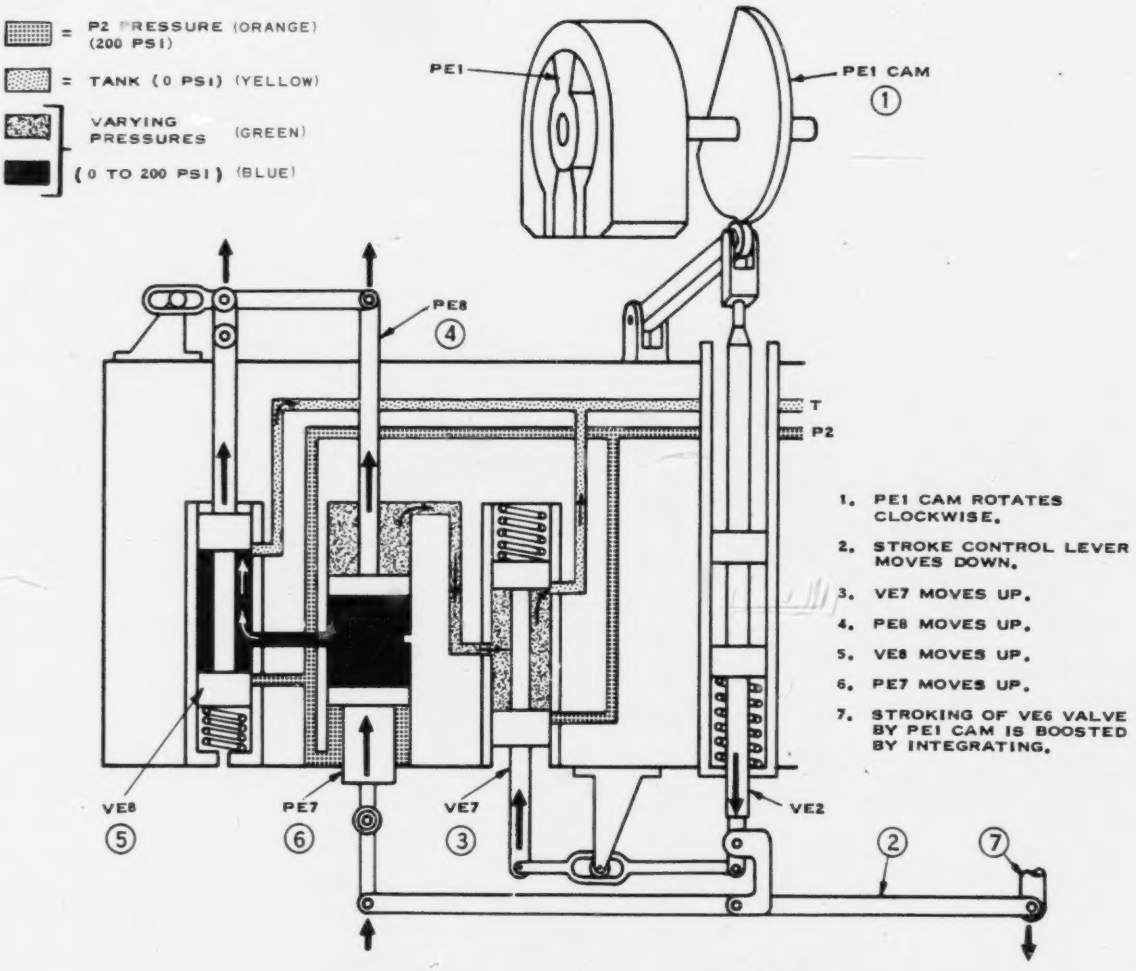
In part C, the effect of integrating is shown. Here a small actuating signal is causing the PE1 cam to rotate, pushing the center of the stroke control lever outward, and stroking VE6 a small amount. In addition to this, however, the integrating system is causing piston PE7 to move upward, pulling the left-hand end of the stroke control lever up with it. As the stroke control lever pivots about its center pivot point, the other end of the lever, the VE6 end, is correspondingly pivoted outward that additional amount. Thus a small actuating signal, with the aid of the integrating system, strokes VE6 to an amount equal to that of the large actuating signal as shown in diagram B in which integrating was not used.

Let's now take a closer look at how the integrating system does all this. In figure 6-21, we see that the plunger of valve VE7 is coupled by a lever to the center of the stroke control lever. In the neutral position, the pressure in the central chamber of VE7 is regulated at 100 psi. When the center of the stroke control lever moves down, the plunger of VE7 moves up, closing off P2 pressure to the central chamber and opening the chamber to the tank line. Since the stem end of PE8 is hydraulically connected to the center of VE7, it, too, is then opened to the tank. P2 pressure at the stem end of PE7 then moves PE7 up, pushing the volume of oil between the two pistons up and, consequently, pushing PE8 up also.

Since PE8 and VE8 are connected by a lever, the motion of PE8 strokes valve VE8 so that oil flows out of the locked column between PE7 and PE8 to the tank, thus increasing the upward movement of PE7. The movement of PE7, which is connected to the left end of the stroke control lever, adds to the stroking of VE6 by the PE1 cam.

SEQUENCE OF OPERATION

Now that we have studied the three main parts of the elevation receiver-regulator, let's take a look at them in action together. To do this,


= P2 PRESSURE (ORANGE) (200 PSI)
= TANK (0 PSI) (YELLOW)
VARYING PRESSURES (GREEN)
(0 TO 200 PSI) (BLUE)
PE1
PE1 CAM
①
PE8
④
T
P2
1. PE1 CAM ROTATES CLOCKWISE.
2. STROKE CONTROL LEVER MOVES DOWN.
3. VE7 MOVES UP.
4. PE8 MOVES UP.
5. VE8 MOVES UP.
6. PE7 MOVES UP.
7. STROKING OF VE6 VALVE BY PE1 CAM IS BOOSTED BY INTEGRATING.
VE8
⑤
PE7
⑥
VE7
③
VE2
②
⑦

53.228
Figure 6-20.—Integrating system schematic.

we'll follow the action, in sequential order, that results from a gun order signal with the gun operating under normal director control. For sequence numbers 1 through 8, refer to figure 6-13 to follow the action.

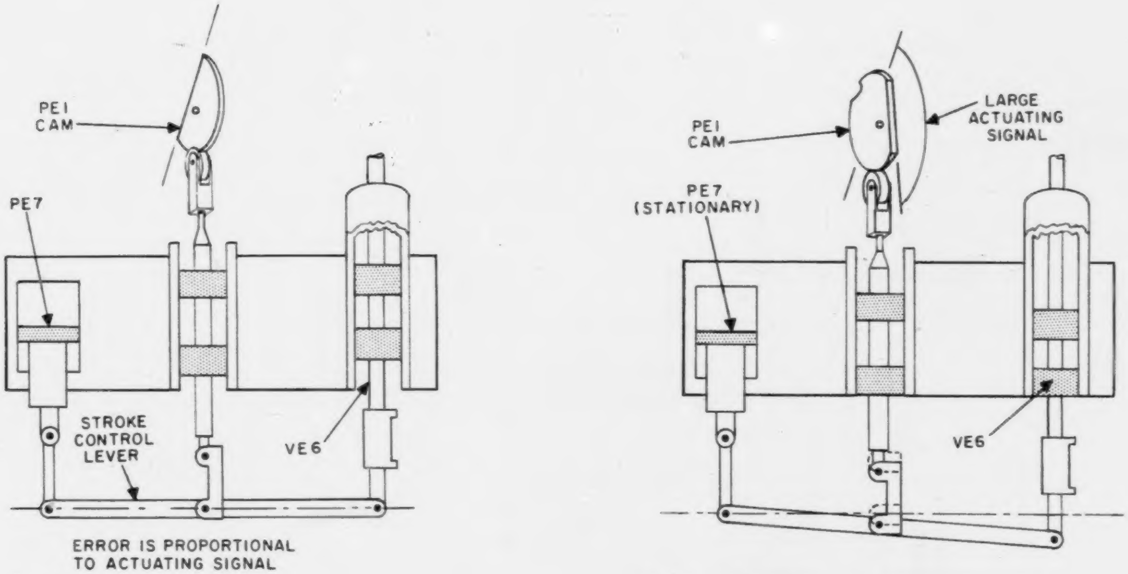
1. The elevation gun order from the computer positions the rotor of the synchro generator.

2. The synchro generator generates a voltage which is used as a reference input to the stator of the synchro control transformer.

3. The voltage that is applied to the stator of the synchro control transformer induces a voltage in the rotor of the synchro control transformer. This voltage is proportional to the gun error and is used as an input voltage to the servoamplifier.

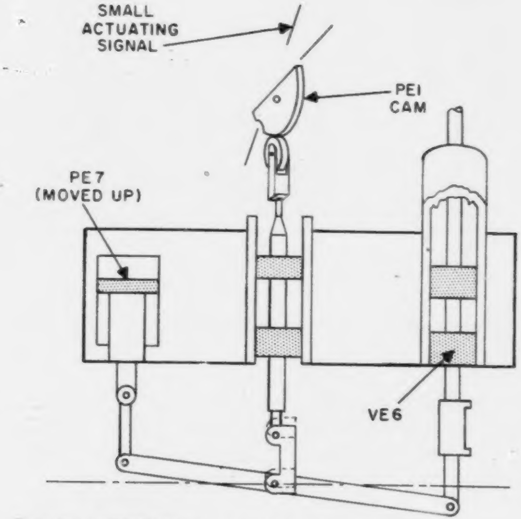
4. The servoamplifier amplifies the alternating voltage and changes it to direct current. The direct current output from the amplifier is used as an input to the torque generator. This direct current is proportional to the alternating voltage from the synchro control transformer.

5. The torque generator rotates valve VE1 against the force of the bias spring. The greater


PE1
CAM
PE7
STROKE
CONTROL
LEVER
VE6
ERROR IS PROPORTIONAL
TO ACTUATING SIGNAL
LARGE
ACTUATING
SIGNAL
PE1
CAM
PE7
(STATIONARY)
VE6

A. ZERO ACTUATING SIGNAL.

B. NO INTEGRATING. A LARGE ACTUATING SIGNAL IS NEEDED TO STROKE VE6.


SMALL
ACTUATING
SIGNAL
PE1
CAM
PE7
(MOVED UP)
VE6

C. WITH INTEGRATING. A SMALL ACTUATING SIGNAL IS NEEDED TO STROKE VE6 AN EQUAL AMOUNT.

53.229

Figure 6-21.—How the integrating system reduces the elevation error.

the error, the greater the input current and the farther the spring can be deflected.

6. When VE1 is rotated in the direction indicated by the arrow, P1 pressure flows into the "green" area of valve VE1 and out through the control line to the "green" side of piston PE1.

7. The control fluid entering the "green" side of piston PE1 causes the piston to rotate in the direction indicated by the arrow.

8. PE1 cam rotates with piston PE1 and strokes the center of the stroke control lever.

NOTE: See figure 6-20 to follow the action through numbers 9 through 14 (Nos. 2 through 7 in the figure.)

9. The center of the stroke control lever is moved downward as illustrated.

10. VE7 strokes upward through action of the lever that is attached to the bottom of VE2 (which is stroked by action of the PE1 cam). As valve VE7 strokes upward, the upper land of the valve opens an outlet to tank pressure, allowing fluid from the top end of piston PE8 to flow out to the tank.

11. Fluid flowing out of the top portion of PE8 causes PE8 to stroke upward.

12. The lever attached to the top end of PE8 is also attached to the top end of VE8. When PE8 strokes upward, VE8 also strokes upward. This action opens an outlet at the bottom of the upper land of valve VE8 to the tank. This allows oil to flow to the tank from the locked column between PE7 and PE8.

13. The combination of PE8 stroking upward and fluid being released from the locked column between PE7 and PE8 to stroke upward. PE7 is attached to the left-hand end of the stroke control lever and moves this end of the lever upward.

NOTE: See figure 6-19 for sequence numbers 14 through 18 (Nos. 3 through 7 in the figure).

14. VE6 valve strokes outward. This stroking is a combination of the stroke transmitted to the center of the stroke control lever by the action of the PE1 cam, plus the stroke transmitted to the left-hand (upper) end of the stroke control lever by the action of the integrating system through piston PE7.

15. When VE6 valve strokes outward, the large stroking piston is vented to the tank through the outer land of VE6 opening the tank line to the central chamber of VE6. This causes the small stroking piston to move inward, the tilt plate to rotate clockwise, and the large stroking piston to move outward.

16. The tilt plate is linked to the VE6 movable sleeve. As the tilt plate rotates, the sleeve follows up the movement of VE6 valve and cuts off the outlet to the tank.

17. The B-end rotates at a speed that is proportional to the tilt plate angle which is in turn proportional to the stroke of valve VE6. Since the B-end is geared to the gun, the gun elevates or depresses according to the signal being received.

18. The rotation of the B-end is transmitted, through response gearing, to the stator of the synchro control transformer.

LOCAL CONTROL

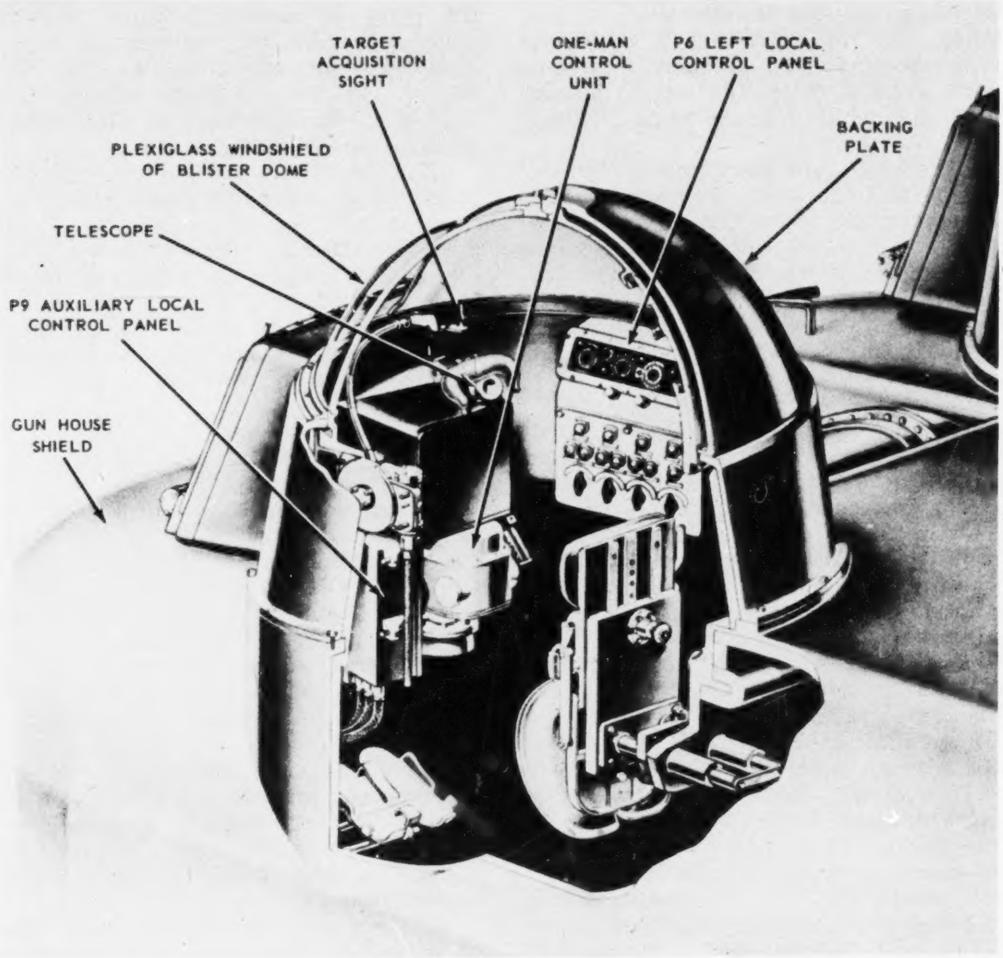
Although the gun is normally operated under remote control, it is often desirable to control gun movement locally. In this type of control, the gun is positioned from either of two one-man control units located within blisters on top of the gun house. Local control is used during starting and normal stowing of the gun, for exercising, practice drill, testing, and for local control of the gun under emergency conditions when director gun orders are not available.

Each local control station consists of a one-man control unit, a local control panel, an auxiliary local control panel, a telescope, and a target acquisition sight. Figure 6-22 shows a cutaway view of the interior of the left local control station.

The gun is switched to local control by means of a switch located on the mount captain's panel in the gun house. This switch, rotary switch MY1, has three positions: OFF, LOCAL, and REMOTE. Turning switch MY1 to the LOCAL position does three things:

1. Allows the transmission starting circuit to be energized;
2. Connects the amplifier to the one-man control units and to a stroke-response potentiometer on the plunger of valve VE6; and
3. Neutralizes the integrating system.

The mount can be operated in local control by only one control unit at a time. Control is normally exercised by the right local control man. The left local control man has control only when it is relinquished by the right man or when the mount captain selects only the left

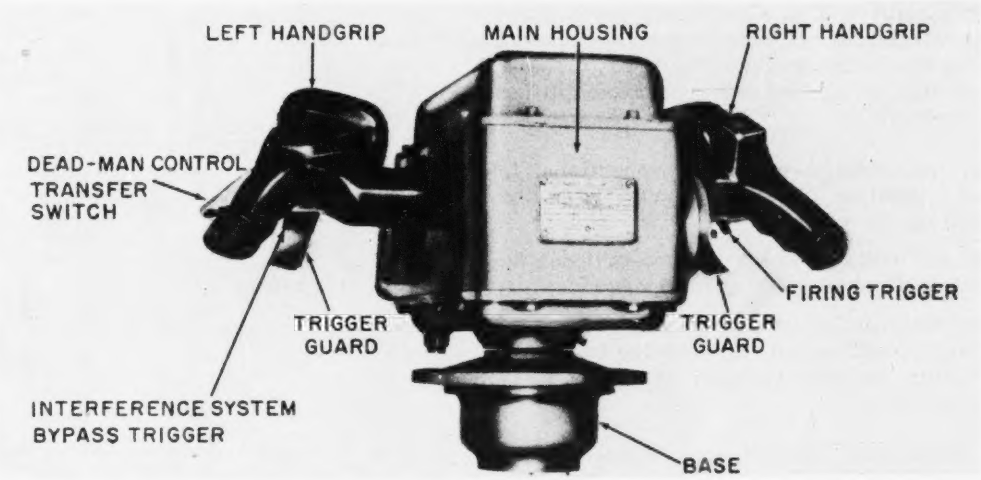

TARGET ACQUISITION SIGHT
ONE-MAN CONTROL UNIT
P6 LEFT LOCAL CONTROL PANEL
BACKING PLATE
PLEXIGLASS WINDSHIELD OF BLISTER DOME
TELESCOPE
P9 AUXILIARY LOCAL CONTROL PANEL
GUN HOUSE SHIELD

53.230
Figure 6-22.—Left local control station, general arrangement.

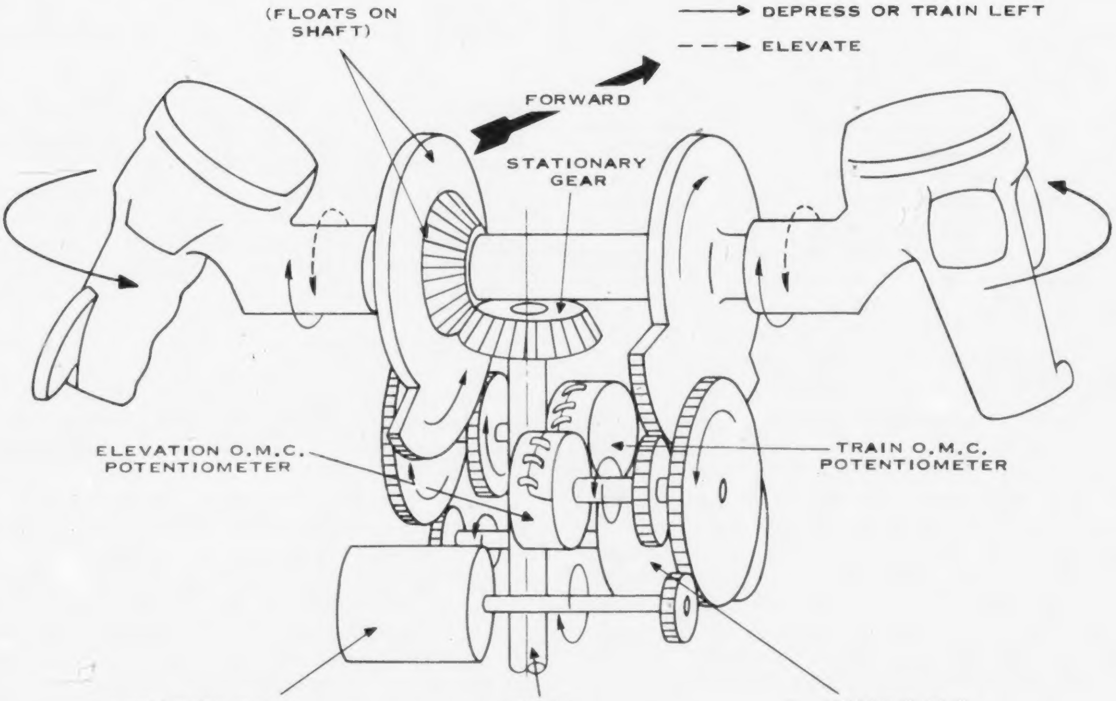
station for control on his P3 control panel. To obtain or retain control of the mount, the local control operator must depress a palm-operated "dead-man" control transfer switch in the left hand-grip of his one-man control unit. This switch is shown in figure 6-23 of a one-man control unit.

The gun is elevated or depressed by rotating the handgrips of the OMC unit as shown by the arrows in figure 6-24. The OMC unit is designed so that the speed of elevation of the gun is proportional to the displacement of the handgrips; the farther the handgrips are rotated, the faster the gun will elevate or depress.

When the handgrips are rotated about the horizontal axis of the cross shaft, a gear assembly drives an elevation potentiometer and an elevation tachometer generator. These elements then generate a gun elevation order signal by applying signal voltages to the servoamplifier of the elevation receiver-regulator. The regulator then strokes the A-end of the elevation power drive and causes the gun to elevate or depress in accordance with the movement of the control unit handgrips.


LEFT HANDGRIP
MAIN HOUSING
RIGHT HANDGRIP
DEAD-MAN CONTROL TRANSFER SWITCH
FIRING TRIGGER
TRIGGER GUARD
TRIGGER GUARD
INTERFERENCE SYSTEM BYPASS TRIGGER
BASE

53.231
Figure 6-23.—One-man control unit.


(FLOATS ON SHAFT)
DEPRESS OR TRAIN LEFT
ELEVATE
FORWARD
STATIONARY GEAR
ELEVATION O.M.C. POTENTIOMETER
TRAIN O.M.C. POTENTIOMETER
ELEVATION O.M.C. TACHOMETER
FIXED SHAFT
TRAIN O.M.C. TACHOMETER

53.232
Figure 6-24.—Schematic arrangement of one-man control unit.

When the handgrips are used to rotate the one-man control unit in a horizontal plane about the vertical shaft, a train order signal is generated and sent to the train receiver-regulator.

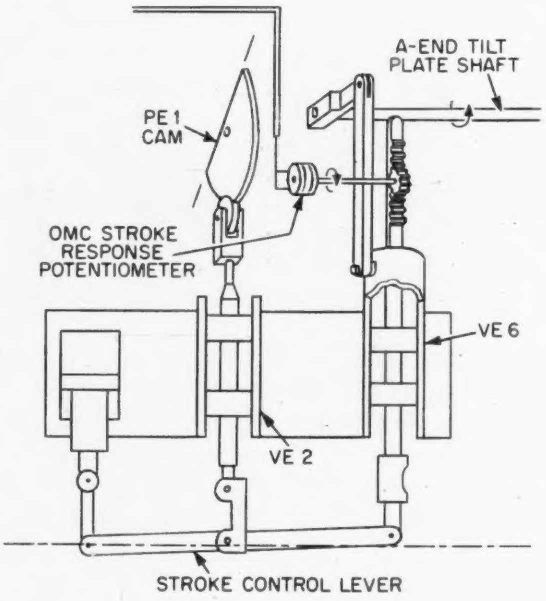
Three voltages are fed into the servoamplifier in local control:

1. An a-c voltage which is proportional to the rotary position of the handgrips from the zero position;
2. A d-c voltage which is proportional to the speed of displacement of the handgrips; and
3. An a-c voltage which is proportional to the rotary position of the stroke-response potentiometer on the plunger of valve VE6. (See figure 6-25).

The difference between the voltage from the handgrips and the voltage from the stroke-response potentiometer is used as the input to the amplifier. The regulator responds to this input to continually reduce the difference towards zero. In so doing, it causes the secondary controller to be stroked proportionately to the movement of the handgrips.

Assume, for instance, that the handgrips are rotated to depress the gun, thus generating an a-c voltage proportional to the displacement. This a-c voltage is applied to the servoamplifier which, in turn, generates a direct current proportional to the a-c voltage. This current causes the torque generator to rotate VE1 valve, causing oil to flow to piston PE1. When piston PE1 rotates counterclockwise, the PE1 cam allows the center of the stroke control lever to be pushed inward by spring pressure. This is, of course, just opposite to the action being shown in figure 6-19 where the PE1 cam is being rotated in a clockwise direction.

With the integrating system neutralized in local control operation, the stroke control lever pivots about the end away from VE6, that is, the PE7 end. VE6 plunger is stroked inward by the stroke control lever, and the rack on the other end of the plunger (fig. 6-25), rotates a gear on the shaft of the stroke-response potentiometer. This causes the potentiometer to generate a voltage proportional to the movement of the plunger. This subtracts from the voltage generated by rotation of the handgrips on the control unit. The plunger moves inward until the voltage from the stroke-response potentiometer just cancels the voltage from the control unit.



53.233

Figure 6-25. — Stroke response in local control.

The secondary controller rotates the tilt plate on the A-end of the hydraulic transmission proportional to the rotation of the handgrips. Therefore, the rate at which the A-end pumps oil to the B-end, and the speed at which the gun depresses, are proportional to the displacement of the handgrips on the OMC unit in the local control station.

AIDED TRACKING

One of the signals from the OMC unit is called aided tracking. Aided tracking assists when a change of rate of speed of gun movement is required.

Each stationary position of the handgrips generates a signal which represents a definite velocity of gun movement. In changing from one position of the handgrips to another a signal, which is dependent on the rate and direction of this change, is added to (or subtracted from) the signal generated by the position of the handgrips. A tachometer generator, geared to the handgrips, provides this signal. This signal from the aided tracking generator increases (or decreases) the stroke of the transmission which changes gun speed an amount more or less than that dictated by the handgrip position. This additional speed in stroking the transmission aids the local control operator by giving him a lead in the tracking of a target.

OTHER IMPORTANT DEVICES

Besides those already covered, a number of other devices are utilized in the control of the 5"/54 hydraulic power drive. Some of the more significant ones will be briefly described here.

LIMIT STOP MECHANISM

The limit stop mechanism has three functions:

1. It limits the travel of the gun.
2. It moves the gun barrel over interference zones.
3. It holds the gun during purging and in the event of synchro power failure or amplifier power failure.

In the first part of this chapter we read that the limit stop mechanism for the twin 5"/38 power drive consisted of a mechanical device which returned the A-end tilt box to neutral when the limit stops were reached. A somewhat more complex system is used in the 5"/54 drive. Here, the A-end tilt plate is returned to neutral through a combination of mechanical shafting, gearing, camming, and lever action which, through either solenoid or direct mechanical action, operate valves in the regulator valve block to hydraulically position the A-end tilt plate.

Incorporated in the limit stop mechanism are the interference elimination mechanism and the limit stop brake. The purpose of the interference elimination mechanism is to prevent the gun barrel from striking any part of the ship's structure or installed equipment. It does this by automatically elevating the gun barrel to clear the obstruction, and then returning the gun to the proper degree of elevation when the mount has trained clear. The interference zones are preset on cams in the train and elevation regulators at the time of installation aboard ship.

The main purpose of the limit stop brake is to function as a safety device to stop the gun in case of a power failure. It is also used to hold the gun when the regulator is purged to remove air from the valves and pistons in the valve block.

PARALLAX ERROR INPUT

The mechanism which corrects for the difference between the direction of the target when viewed from the director and when viewed from the gun is called the parallax corrector. This mechanism is located in the after compartment of the regulator.

The parallax corrector operates by feeding a mechanical rotation into the B-end response gearing of the regulator. This signal adds to the B-end response signal.

The parallax corrector is actuated by an error signal the same way that the regulator is actuated. It is not capable of following as fast a signal as the regulator, however, and for this reason, the parallax error is used as another input to the servoamplifier. This allows the regulator to compensate for the slow response of the parallax corrector.

NOTE: For detailed information on these devices, refer to OP 1764, Volume 10.

SIMILARITIES OF SYSTEMS

In comparing the control equipment of the 5"/54 drive with that of the twin 5"/38 drive, we will find that many of the devices and mechanisms in each will have similar functions—even though they may not physically resemble each other, or be called by the same name. For instance, in the twin 5"/38 drive, dithering is accomplished through an oscillator incorporated into the sump pump. In the 5"/54 drive, the same effect is accomplished by introducing an a-c voltage to the grid of V14 tube in the servoamplifier. Some other such similarities in designed purpose will be pointed out here.

Although the regulators for the two systems appear to differ greatly in their individual makeup, they both perform a similar basic function; that is, they both control the power drive in response to electrical order signals. In local control, rotation of the handwheels of the 5"/38 transmits a mechanical input into the indicator-regulator. The indicator-regulator combines this mechanical input with B-end response in exactly the same manner that electrical orders are combined in automatic control to control the power drive. In the 5"/54, rotation of the handgrips of the OMC unit controls the power drive in local control. Here, however, the rotation transmits an electrical signal to the servoamplifier of the receiver-regulator. The 5"/54 OMC units have no alternative methods of control whereas the 5"/38 drive can be operated in two other methods of control besides LOCAL from the handwheel stations. These are HAND and MANUAL, as described in the first section of this chapter.

The limit stop mechanisms of the two systems have been previously compared. In the event of synchro power failure, both systems employ devices which, although quite different in construction, perform the same function— that of stopping any further movement of the gun.

By carefully studying most any two of the various types of power drive control systems utilized in today's Navy, you will very likely discover many components which likewise perform similar functions in their respective drives.

Let's briefly review the key operational points of the elevation receiver-regulator used in the control equipment for the 5"/54 power drive.

The elevation receiver-regulator consists of three parts: The primary controller, the secondary controller, and the integrating system.

The primary controller generates the actuating signal which is a measure of the error between the gun elevation and the elevation gun order. This actuating signal drives the secondary controller which strokes the hydraulic transmission so that the gun is driven into correspondence with the gun order.

The error under static conditions when the gun order is not changing is zero. When the elevation order changes, there is a dynamic error. The integrating system reduces this dynamic error by driving the secondary controller an additional amount through action of the stroke control lever.

5"/54 MOD 9 DIFFERENCES

The following information is primarily for the purpose of pointing out the differences between the power drive control equipment used with the Mod 9 and the Mods 1 through 8. One feature of the Mods 1 through 8 control equipment that was deemed unnecessary and eliminated was the right hand local control station located in the gun house.

The major changes to the Mod 9 are: a new type receiver-regulator which incorporates the latest advances drawn from other, more recent ordnance systems such as the Tartar and Terrier guided missile launching systems. Other changes include a solid state amplifier (electronic servo control unit) which uses transistors rather than vacuum tubes. Eliminated from the receiver-regulator are most of the control valves and their valve blocks. A larger electrohydraulic servo valve (Moog valve) was incorporated in the new design. The servo valve directly controls the A-end stroking pistons which eliminate many valves and valve linkages used in the receiver-regulator for the Mods 1 through 8.

An improved nonpointing zone system is in the new power drive control system providing a three zone capability for each gun mount. The nonpointing zone system prevents the gun from pointing toward the structure of the ship. The areas of ship structure that could be endangered either through direct physical interference from the gun or by accidental firing are called nonpointing zones. The nonpointing zone system (automatic pointing cutout system) is located in the receiver-regulators.

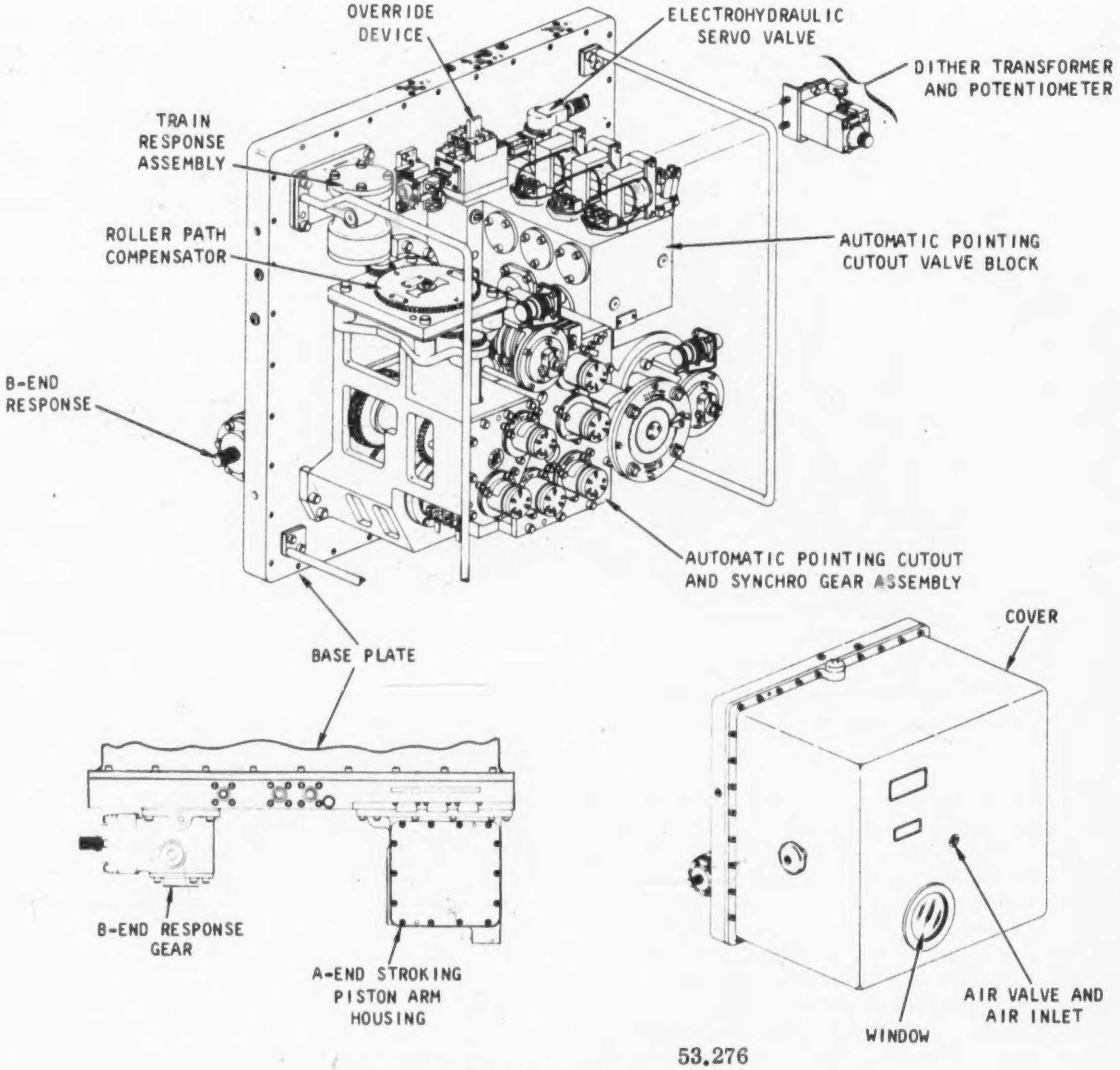
Also added to the Mod 9 system is a wet-type power off brake of a design used in missile launching systems. This brake provides for smoother deceleration in case of power failure and is more reliable than the original brakes used with Mods 1 through 8.

RECEIVER-REGULATOR

The receiver-regulators for the Mod 9 gun mounts train and elevation power drives perform the same functions and have the same physical location as the receiver-regulators for the Mods 1 through 8. Components of the receiver-regulators, figure 6-26, are: (1) cover, (2) base plate, (3) automatic pointing-cutout and synchro gear assembly, (4) automatic pointing cutout valve block, (5) dither transformer, (6) A-end linkage, and (7) B-end response gear assembly.

Regulator Cover

The one piece cover (fig. 6-26) has a watertight and airtight seal which protects regulator components. A window permits observation of indicating dials mounted on the synchro assembly. An air valve and an air inlet in the top of the


OVERRIDE DEVICE
ELECTROHYDRAULIC SERVO VALVE
DITHER TRANSFORMER AND POTENTIOMETER
TRAIN RESPONSE ASSEMBLY
ROLLER PATH COMPENSATOR
AUTOMATIC POINTING CUTOUT VALVE BLOCK
B-END RESPONSE
AUTOMATIC POINTING CUTOUT AND SYNCHRO GEAR ASSEMBLY
COVER
BASE PLATE
B-END RESPONSE GEAR
A-END STROKING PISTON ARM HOUSING
WINDOW
AIR VALVE AND AIR INLET

53.276
Figure 6-26.—Receiver-regulator.

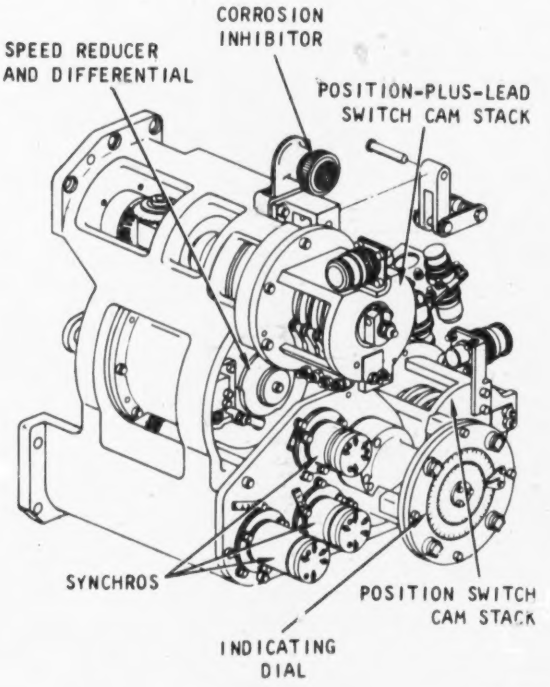
cover permits the air within the cover to be replaced with inert gas.

Base Plate

The base plate of the receiver-regulators serves as a chassis for supporting the various mechanical and electrical components to the receiver-regulator. The A-end stroking piston arm and the B-end response gear assembly are mounted on the underside of the base plate, figure 6-26.

Automatic Pointing Cutout and Synchro Gear Assembly

The automatic pointing cutout and synchro gear assembly, figure 6-27, contains synchros,


CORROSION INHIBITOR
SPEED REDUCER AND DIFFERENTIAL
POSITION-PLUS-LEAD SWITCH CAM STACK
SYNCHROS
POSITION SWITCH CAM STACK
INDICATING DIAL

53.277
Figure 6-27.—Automatic pointing-cutout and synchro gear assembly (train).

a tachometer generator, a position-plus-lead switch cam stack, limit stops, indicator dials, a position switch cam stack, a speed reducer, and a differential speed reducer. The synchros receive order signals from the fire control system and process them for use in positioning the mount. The automatic pointing cutouts prevent the gun from damaging ship's structure. The position and position-plus-lead cam stacks and the limit stops aid in bringing the mount to a gradual stop. Indicating dials show the position of the mount in train and elevation. The position switch cam stack provides mount position information for use by the automatic pointing cutout system. The differential speed reducer transmits the B-end responses to the synchros, the speed reducer, the indicator dials, and the position switch cam stack.

The receiver-regulators for train and elevation units are similar except that the elevation unit receives a train response input into the roller path compensator.

Automatic Pointing-Cutout Valve Block

The automatic pointing-cutout valve block, figure 6-28, includes a nonpointing zone piston, solenoid valves, solenoids, an override device, and an electrohydraulic servo valve. The override device extends from the inboard side of the valve block. The limit-stop lever is connected to the override device, and the override device is connected to the electrohydraulic servo valve.

Servo Valve

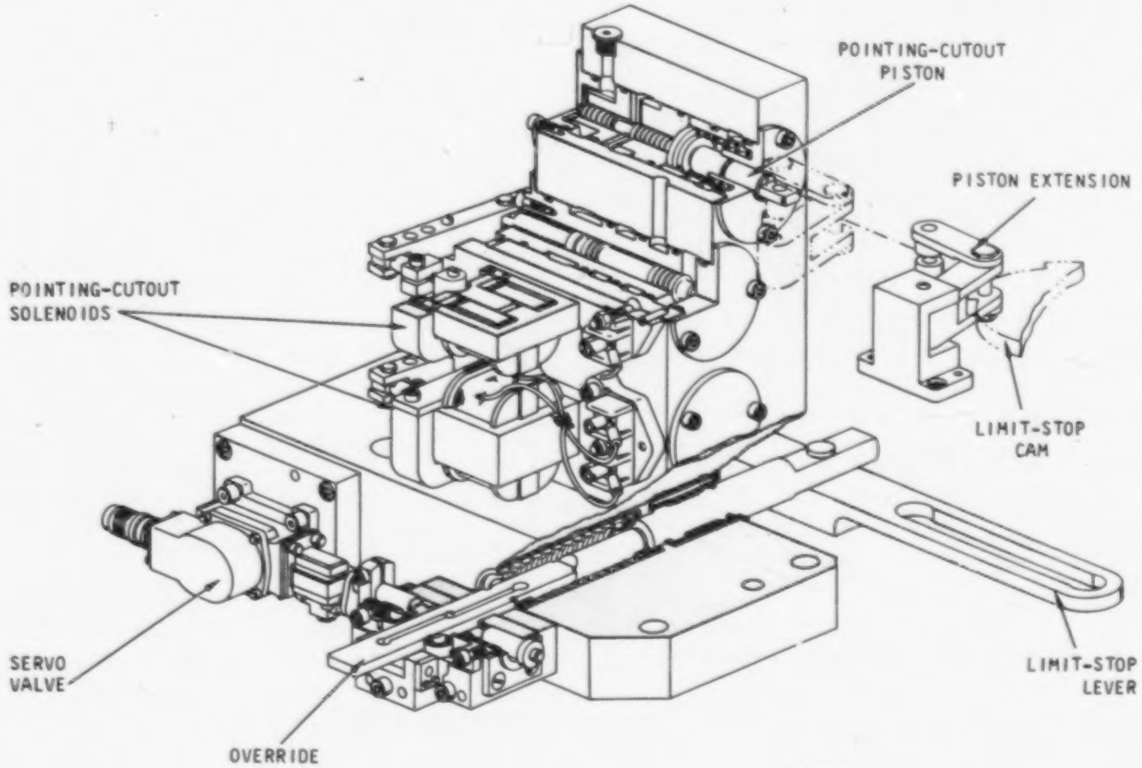
The electrohydraulic servo valve converts electrical signals from the electronic servo control amplifier into controlled hydraulic flow to the hydraulic transmission. The servo valve is mounted to the automatic pointing cutout valve block, figure 6-28. Four parts (a pressure part, a return part, and two control parts) in the bottom of the servo valve body connect to openings in the side of the automatic pointing-cutout valve block.

Dither Transformer

The dither transformer, figure 6-29, is a 60 cycle stepdown type wired into the electrohydraulic servo valve force motor circuit. The transformer dither signal prevents static friction from causing the servo valve to stick by passing alternating current through the servo valve and thus keeping it constantly vibrating. A potentiometer mounted on the top of the dither transformer is adjusted to control the strength of the dither signal.

A-End Response Linkage

The A-end response linkage is mounted on the receiver-regulator base plate. It consists of a limit-stop lever, a cam linkage, a stroke response potentiometer, and a switch actuator, figure 6-30. The A-end stroking piston moves the cam linkage and the limit-stop lever. The cam linkage shifts the center arm of the stroke response potentiometer. The stroke response potentiometer provides the servoamplifier with a velocity feedback signal which helps to control the output of the servo valve. The purpose of the A-end switch actuator assembly is to indicate when the A-end hydraulic unit is at neutral.



53.278
Figure 6-28. — Pointing-cutout valve block (train).

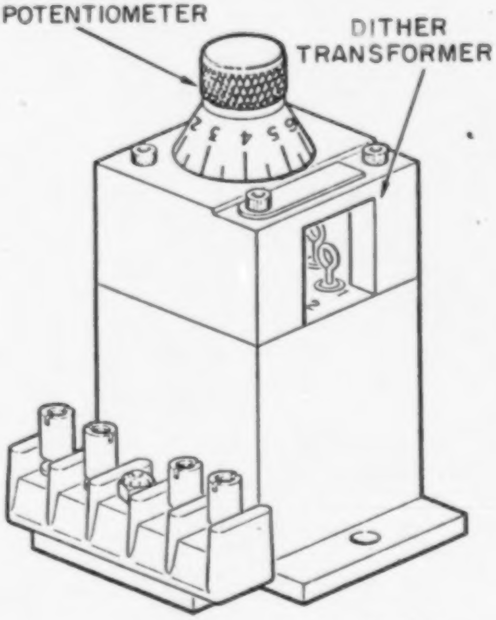
B-End Response Gear Assembly

The B-end response gear assembly (figure 6-26) transmits B-end output movements from the hydraulic transmission unit to the synchros of the automatic pointing-cutout and synchro gear assembly. The response gear assembly consists of a response housing, shafts, bearings, and gears. The response shaft, which supplies B-end response movements, is equipped with two flexible couplings and a vernier adjustment to aid in alignment procedures.

ELECTRONIC SERVO CONTROL UNIT

The electronic servo control unit (servoamplifier) is common to the train and elevation systems. It receives, processes, and converts a small a-c position error signal from the synchros to a d-c signal large enough, and of proper polarity, to activate the electrohydraulic servo valve on the receiver-regulators. The servoamplifier, figure 6-31, contains front panel controls for adjustment and alinement and 13 plug-in module boards (6 for train, 6 for elevation, and one common power supply module board). The respective module boards for the train and elevation systems are identical and are interchangeable. Each module board has a component designation of PC (printed circuit board) and is designed to perform a different function. The module boards for the train and elevation amplifier are designated as follows:

PC1	Shaping and logic circuit.
PC2	Position amplifier.
PC3	Compensation circuit.



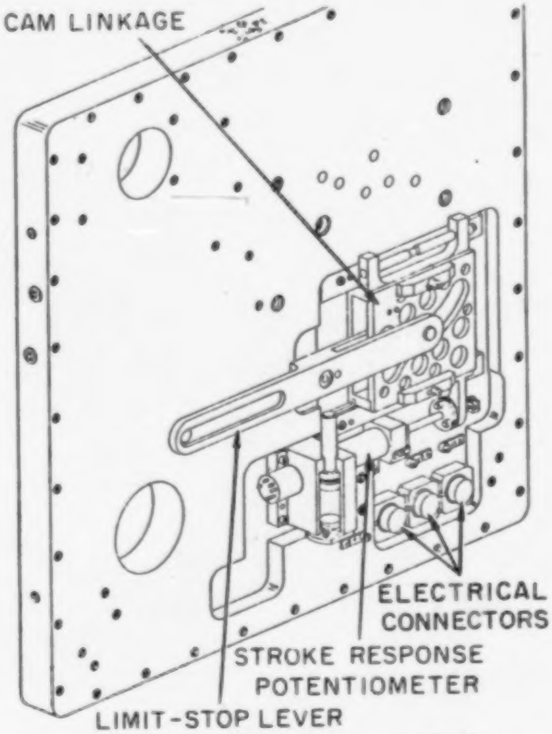
53.279
Figure 6-29.—Dither transformer.

PC4	Compensation amplifier.
PC5	Stroke amplifier.
PC6	Filter circuit.
PC7	Power supplies (common to both systems).

For the following functional analysis of the servoamplifier, refer to figure 6-32.

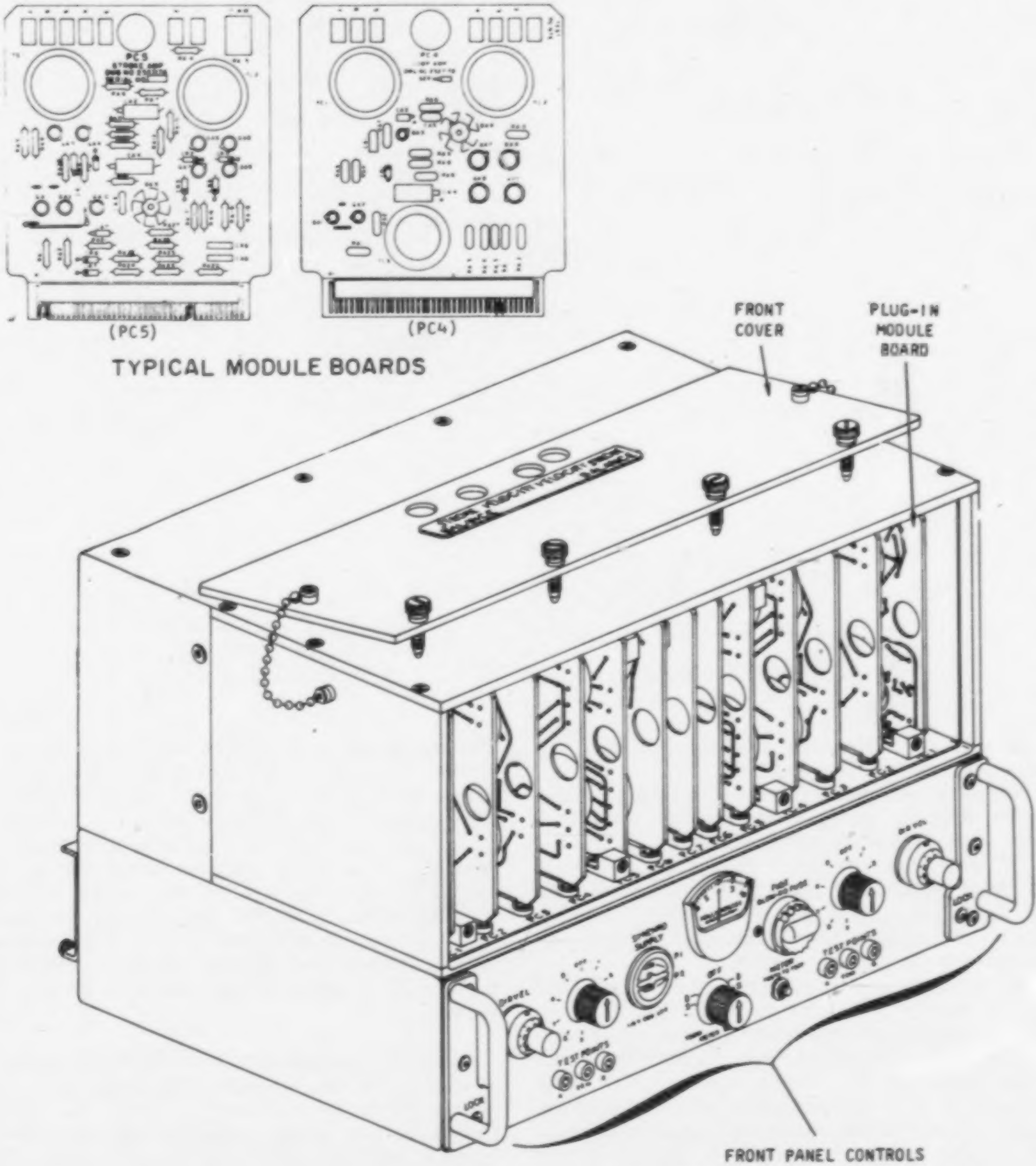
A command signal from the fire control system (FCS) is applied to the 1X and 36X synchros. The output of these synchros is applied to PC1. When the position error signal is less than 2 degrees, the 36X output of PC1 is applied to PC2 through a transistor switch. When the position error is greater than 2 degrees, the 1X output of PC1 is applied to PC2. A switching signal from PC1 is applied to PC3.

Module board PC2 amplifies the 1X or 36X position error signal and adds a d-c feedback voltage (B-end velocity signal from a tachometer) to the position error signal. The output of PC2 is applied to PC3. When the position error signal is within 1 degree of the command signal, the switching signal from PC1 triggers the switching oscillator in PC3 and the switching transistors apply the output of PC3 to PC4, and then to PC6. The purpose of PC4 is to amplify the position error signal when the signal is less than 42 minutes to maintain system accuracy when the error signal is small. When the position error signal is 2 degrees or more, the switching signal from PC1 triggers the switching oscillator in PC3 and the switching transistors apply the output of PC3 directly to PC6. Module board PC6 processes the position error signal, director velocity signal, and A-end velocity response signals to obtain a composite output (stroke servo error) signal.

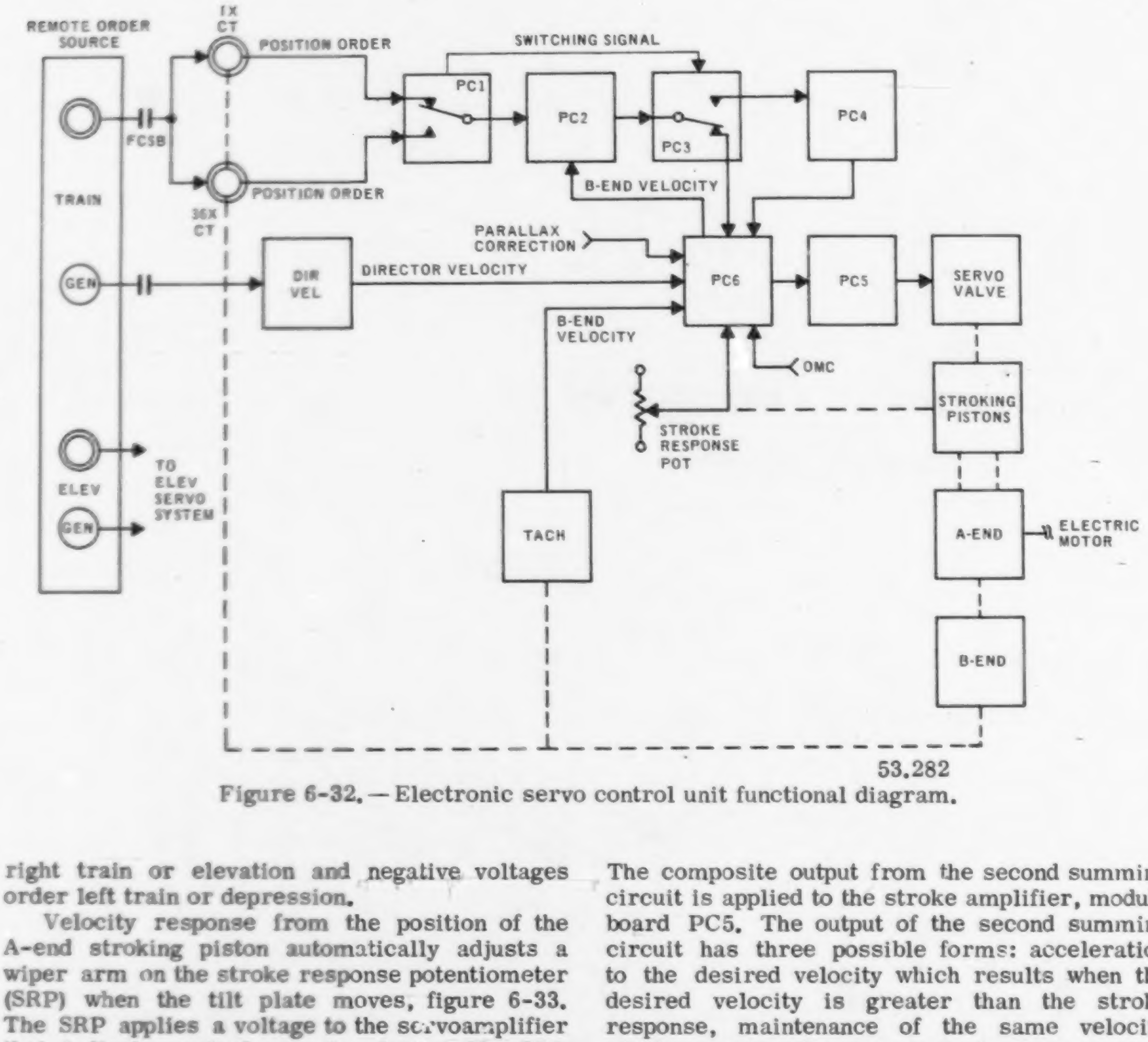


53.280
Figure 6-30.—Base plate (elevation).

The director velocity signal comes from a tachometer geared to the controlling director (position order source) which supplies a d-c velocity signal to the servoamplifier. The director velocity signal represents the rate of change of the position signal. The tachometer provides 1/2 volt for each degree per second of position signal change. Positive velocity voltages order


(PC5)
(PC4)
TYPICAL MODULE BOARDS
FRONT COVER
PLUG-IN MODULE BOARD
FRONT PANEL CONTROLS

53.281
Figure 6-31.—Electronic servo control unit.


REMOTE ORDER SOURCE
1X CT
POSITION ORDER
SWITCHING SIGNAL
PC1
PC2
PC3
PC4
FCSB
TRAIN
POSITION ORDER
B-END VELOCITY
36X CT
PARALLAX CORRECTION
DIR VEL
DIRECTOR VELOCITY
PC6
PC5
SERVO VALVE
GEN
B-END VELOCITY
OMC
STROKE RESPONSE POT
STROKING PISTONS
TO ELEV SERVO SYSTEM
ELEV
GEN
TACH
A-END
ELECTRIC MOTOR
B-END

53.282

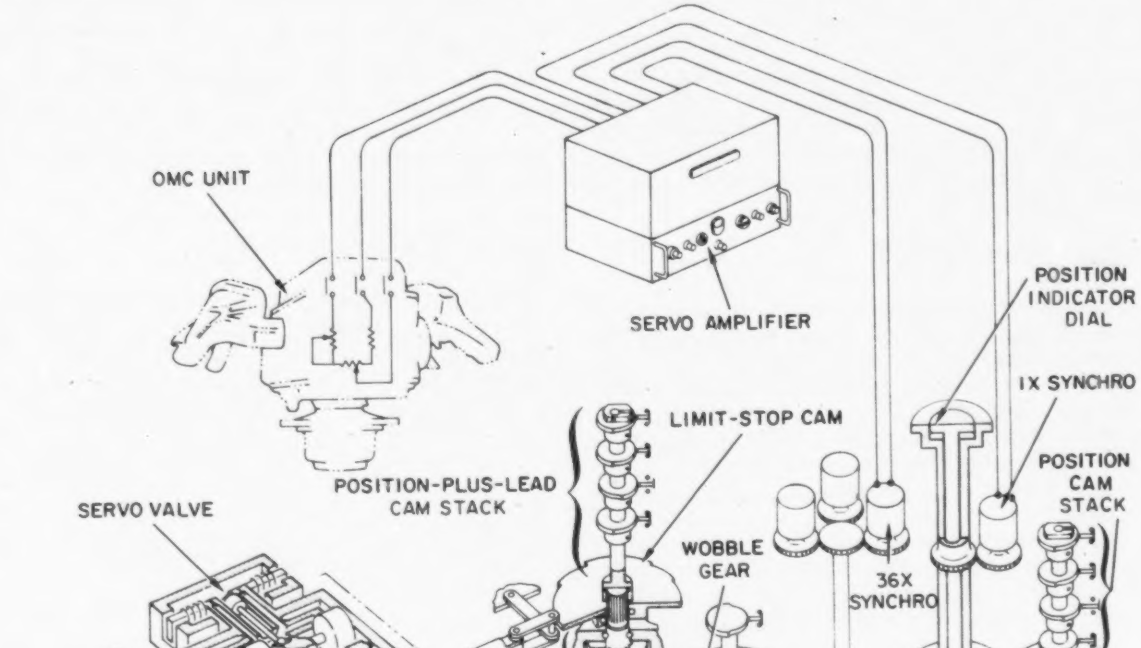
Figure 6-32.—Electronic servo control unit functional diagram.

right train or elevation and negative voltages order left train or depression.

Velocity response from the position of the A-end stroking piston automatically adjusts a wiper arm on the stroke response potentiometer (SRP) when the tilt plate moves, figure 6-33. The SRP applies a voltage to the servoamplifier that indicates actual mount velocity. The SRP output is negative for increasing orders and positive for decreasing orders.

A velocity and summing circuit, part of module board PC6, acts to match the director velocity signal with the other signals and shapes a response to control the acceleration and deceleration of the servo system. The first summing circuit algebraically adds the position error and the director velocity signal to produce one output signal. This signal is applied to the second summing circuit which is subtracted from the A-end velocity signal from the SRP. The composite output from the second summing circuit is applied to the stroke amplifier, module board PC5. The output of the second summing circuit has three possible forms: acceleration to the desired velocity which results when the desired velocity is greater than the stroke response, maintenance of the same velocity which results when the two signals are equal and their combined output is zero, and deceleration to the desired velocity which results when the stroke response is greater than the desired velocity.

When it is necessary to reverse the direction of system travel, however, the desired velocity is in the opposite direction from the stroke response. The stroke response now adds to the desired velocity. The stroke servo error then orders a greater rate of deceleration. A positive stroke error causes either acceleration for an


OMC UNIT
SERVO AMPLIFIER
POSITION INDICATOR DIAL
1X SYNCHRO
LIMIT-STOP CAM
POSITION-PLUS-LEAD CAM STACK
SERVO VALVE
WOBBLE GEAR
36X SYNCHRO
POSITION CAM STACK
LIMIT-STOP MECHANISM
SPEED REDUCER
LIMIT-STOP DRIVE GEAR
OVERIDE DEVICE
A-END INPUT
STROKE RESPONSE POTENTIOMETER
TACH
B-END RESPONSE GEAR
LIMIT-STOP LEVER
CAB UNIT
A-END CAM LINKAGE
A-END STROKING PISTONS
AUXILIARY GEAR PUMP
MOTOR

53.265

Figure 6-33.—Synchro gearing and limit-stop assembly.

increasing order or deceleration for a decreasing order, figure 6-34.

Module board PC5 modulates, amplifies, and demodulates the d-c servo error voltage from PC6. The modulator circuit converts the d-c error voltage into either an in phase or out of phase 400 cycle a-c signal. The amplifier (three stage) amplifies the modulated 400 cycle signal before it is applied to the demodulator. The demodulator converts the a-c input to a d-c output to operate the force motor coils of the servo valve.

FORCE MOTOR COILS

The force motor of the servo valve (fig. 6-34) converts the electrical input supplied by the servoamplifier to a mechanical displacement. The electrical signal applied to the force motor coils generates a torque that causes an armature to move and bend on a flexure tube support. A flapper assembly attached to the armature moves with it toward one nozzle (N) and away from the other.

Differential pressures caused by the flapper movements between the nozzles move a plunger (UVT1) of a four way valve which regulates hydraulic output to the A-end stroking pistons.

Figure 6-34 illustrates the servo valve positioned for a positive signal. The force motor has shifted the armature and flapper to a position shown in figure 6-34. This shift decreases flow through nozzle N1 and increases flow through N2 resulting in a pressure differential between chambers C1 and C2. Since C1 pressure is greater, the plunger (UVT1) moves to the right, UCT2 is ported to tank, and UCT3 receives servo pressure. The control pressure at stroking piston UCT3 is now greater than the pressure at stroking piston UCT2, causing the tilt plate to move in a clockwise direction. Clockwise movement accelerates the mount during increasing orders and decelerates it during decreasing orders. For negative signals, UVT1 plunger action is reversed and the flapper shifts to block the flow through N2 causing the tilt plate to move counterclockwise.

When plunger UVT1 moves from center, the feedback spring (fig. 6-34) applies a torque to the armature. This torque, which is proportional to the plunger displacement, opposes the torque developed by the force motor. As the order is complied with, and as response causes the signal to decrease, the torque on the armature returns the flapper to neutral.

The servo valve has a mechanical override device (fig. 6-33) that does not affect valve operation under normal conditions. When the limit-stop system assumes control of the power drive, however, the mechanical override device positions the servo valve regardless of the signal input to the force motor coils. Whenever the limit-stop system is in control, a protective device (a 3K resistor) is placed in series with the output from the stroke servo amplifier to prevent damage to the force motor.

LIMIT-STOP MECHANISM

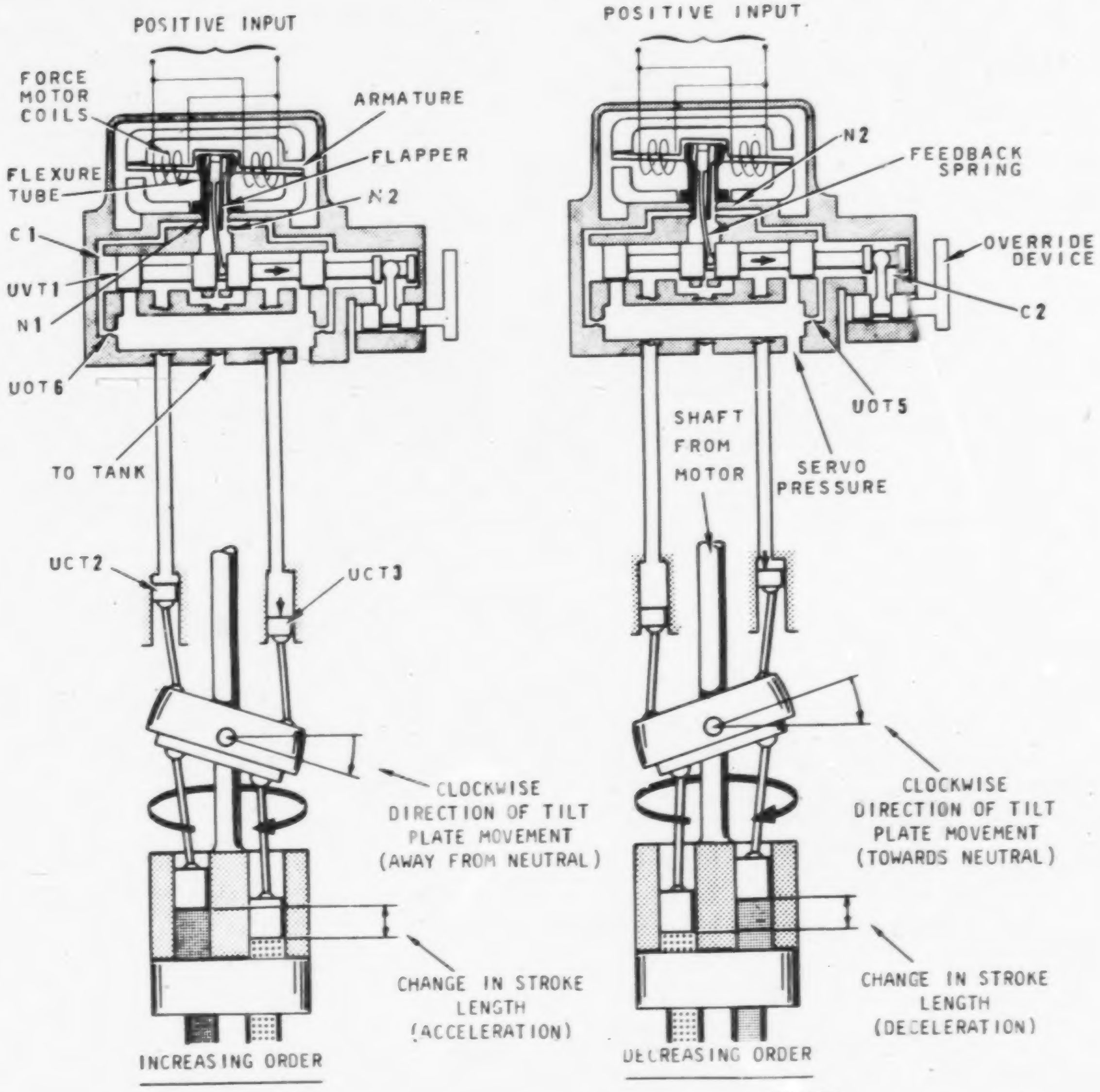
The limit-stop mechanisms prevent the gun from moving beyond its designed limits and damaging the ship's structure or gun mount equipment. If a limit is reached while the gun is moving or the mount is rotating, the limit-stop mechanism (fig. 6-35) returns the A-end tilt plate of the hydraulic transmission unit to neutral and stops gun movement. The components of the limit-stop mechanisms are the wobble gear, the limit-stop assembly, the limit-stop lever, and the override device.

Wobble Gear

The wobble gear (figure 6-35) functions as a differential speed reducer in the limit-stop mechanism. (A mechanical differential gear arrangement adds or subtracts mechanical inputs). The train and elevation limit-stop mechanisms are similar in operation, only the train, limit-stop mechanism is discussed in detail.

When the mount is moving in train, response gearing from the train B-end rotates the wobble gear B-end input. The wobble gear transfers B-end rotation to the limit-stop output. In addition, the A-end stroking piston, through the limit-stop, adds a lead to the wobble gear (fig. 6-35). This lead, proportional to train velocity, allows time for smooth deceleration of the mount.

A limit-synchronized switch (SIT-4) and cam (fig. 6-35) are safety features which stop the train power drive whenever the limit-stop crank arm (fig. 6-35) is beyond 60 degrees from its neutral position in either direction. If during maintenance or repair, the crank arm is displaced 180 degrees out of position, limit-stop action would be reversed and the mount would drive into the limit stops and serious damage could result. To prevent this, limit-synchronized cam opens limit switch SIT-4 which in turn


POSITIVE INPUT
FORCE MOTOR COILS
ARMATURE
FLAPPER
FLEXURE TUBE
N2
C1
UVT1
N1
UOT6
TO TANK
UCT2
UCT3
CLOCKWISE DIRECTION OF TILT PLATE MOVEMENT (AWAY FROM NEUTRAL)
CHANGE IN STROKE LENGTH (ACCELERATION)
INCREASING ORDER
POSITIVE INPUT
N2
FEEDBACK SPRING
OVERRIDE DEVICE
C2
UOT5
SHAFT FROM MOTOR
SERVO PRESSURE
CLOCKWISE DIRECTION OF TILT PLATE MOVEMENT (TOWARDS NEUTRAL)
CHANGE IN STROKE LENGTH (DECELERATION)
DECREASING ORDER

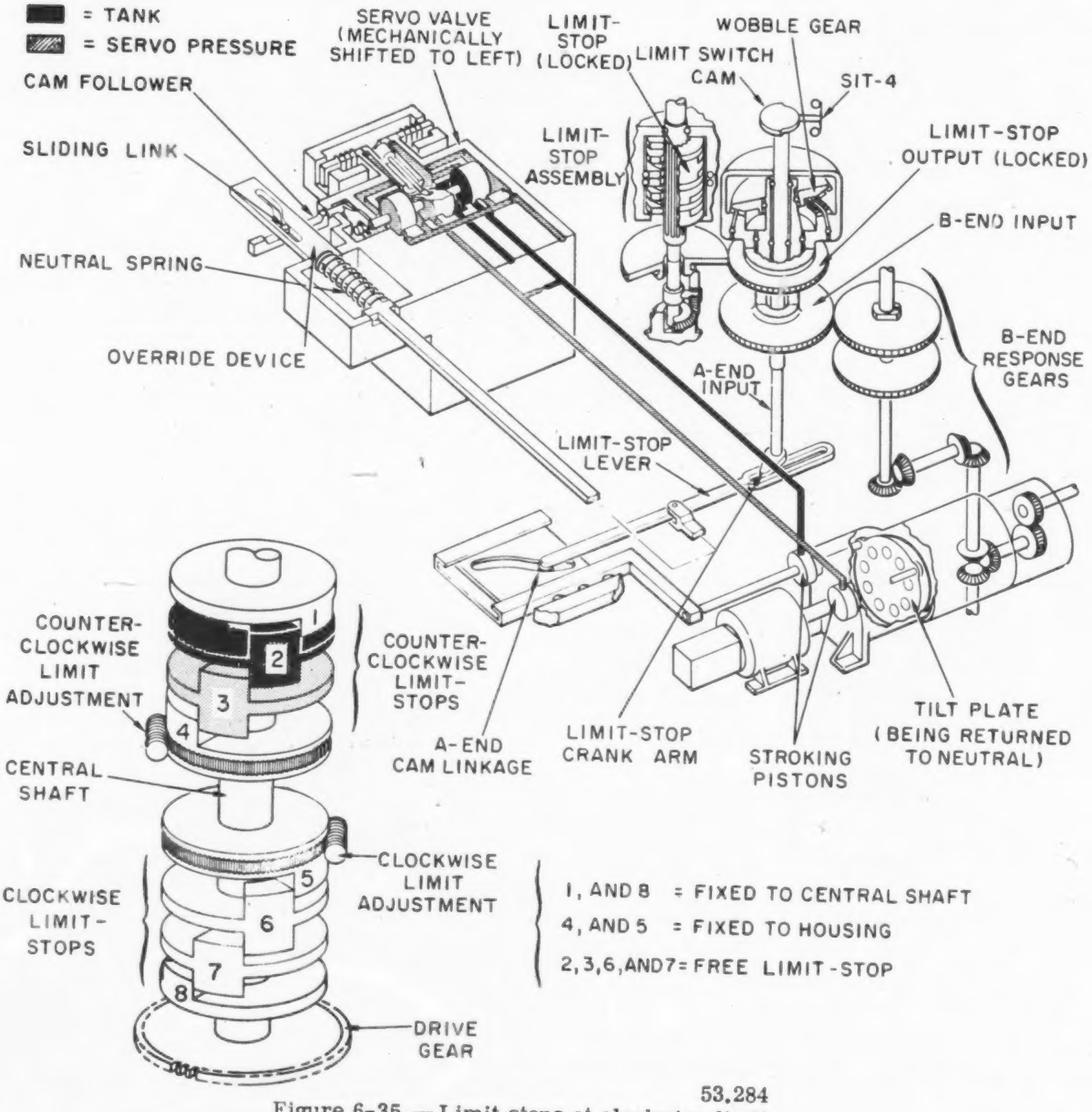
53.283

Figure 6-34. — Positive signal in force motor coils.

opens the train contactor circuit to the train motor, thus stopping the gun mount movement.

Limit-Stop Assembly

The limit-stop assembly, figure 6-35, consists of eight limit stops, a central shaft, and a drive gear. The eight limit stops are divided into two sets of four stops each. One set forms the clockwise train limit, and the other set forms the counterclockwise train limit. Each set consists of one limit stop splined to the central shaft, two limit stops free to rotate on the central shaft, and one adjustable limit stop


■ = TANK
▨ = SERVO PRESSURE
CAM FOLLOWER
SLIDING LINK
NEUTRAL SPRING
OVERRIDE DEVICE
SERVO VALVE (MECHANICALLY SHIFTED TO LEFT)
LIMIT-STOP (LOCKED)
LIMIT SWITCH CAM
WOBBLE GEAR
SIT-4
LIMIT-STOP ASSEMBLY
LIMIT-STOP OUTPUT (LOCKED)
B-END INPUT
B-END RESPONSE GEARS
A-END INPUT
LIMIT-STOP LEVER
COUNTER-CLOCKWISE LIMIT ADJUSTMENT
COUNTER-CLOCKWISE LIMIT-STOPS
A-END CAM LINKAGE
LIMIT-STOP CRANK ARM
STROKING PISTONS
TILT PLATE (BEING RETURNED TO NEUTRAL)
CENTRAL SHAFT
CLOCKWISE LIMIT ADJUSTMENT
CLOCKWISE LIMIT-STOPS
1
2
3
4
5
6
7
8
DRIVE GEAR
1, AND 8 = FIXED TO CENTRAL SHAFT
4, AND 5 = FIXED TO HOUSING
2,3,6,AND7= FREE LIMIT-STOP

53.284
Figure 6-35.—Limit stops at clockwise limit.

fixed to the limit-stop housing. For this analysis of limit stop operation, assume that the mount is training clockwise. In clockwise rotation only the clockwise limit stops are used, the counterclockwise limit stops rotate freely.

As the mount trains, the drive gear, the center shaft, and limit stops 1 and 8 are rotated counterclockwise by B-end response (fig. 6-35). As limit stops 1 and 8 rotate, the projections on their cam surfaces capture limit stops 2 and 7. The counterclockwise stops 1, 2 and 3 are moving away from stationary limit stop 4 and have no effect on clockwise limit stop operation. As the mount continues its rotation, limit stop 7 captures limit stop 6 and moves toward stationary limit stop 5. When the mount reaches its rotation limit, limit stop 6 strikes the stationary clockwise limit stop 5 and locks the entire limit-stop assembly.

With the limit stop output locked, the wobble gear can no longer transfer B-end rotation to the limit-stop assembly (fig. 6-35). Since the mount and the B-end response gear are still rotating, the wobble gear transfers B-end rotation to the limit-stop lever.

Limit-Stop Lever

One end of the limit-stop lever is attached to a cam surface linked to the A-end stroking piston (fig. 6-35). The other end is attached to the wobble gear by the limit-stop crank arm.

Since one end of the limit-stop lever is held hydraulically by the A-end stroking piston, movement from B-end response is transmitted mechanically to the override device by the limit-stop crank arm. The override device positions the servo valve to port hydraulic fluid to the opposite stroking piston to decelerate the gun and stop gun movement.

Override Device

The override device is connected to the servo valve by a sliding link. During normal operation, the movement of the servo valve as it responds to the electrical order signal is not great enough to contact the override device. When a limit stop action occurs, the diagonal portion of the override device raises the cam follower and the override device. The sliding link then contacts the upper shoulder of the servo valve, moving the servo valve piston to mechanically override the electrical signal to the force motor and decelerate the gun. A neutral spring (fig. 6-35) holds the override device at neutral when the power drive is not under limit stop control.

AUTOMATIC POINTING CUTOUT SYSTEM

The automatic pointing cutout system prevents the gun from pointing toward the structure of the ship. The areas of ship structure that could be endangered, either through direct physical interference from the gun or by accidental firing, are called nonpointing zones. Figure 6-36 shows a simplified arrangement of the nonpointing zones aboard ship. Although a nonpointing zone system can be arranged on one, two, or three levels, the following text assumes that a three level nonpointing zone arrangement is in use.

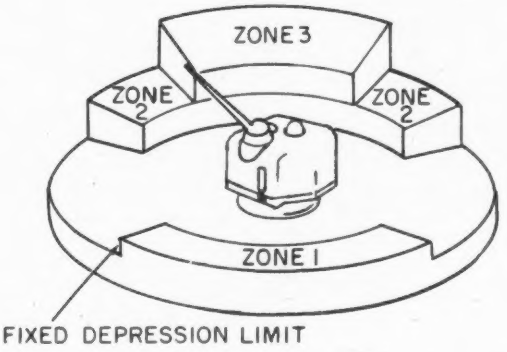
The pointing cutout system receives position and position plus lead signals from the train and elevation systems. When position-plus-lead signals indicate that the mount is approaching a nonpointing zone, the pointing-cutout system mechanically overrides gun laying orders and detours the gun around the zone. When position signals indicate that the gun has moved away from a nonpointing zone, the gun laying orders resume control of the mount.

Note: The automatic pointing cutout system actuates the train and elevation limit-stop mechanisms to override gun laying orders.

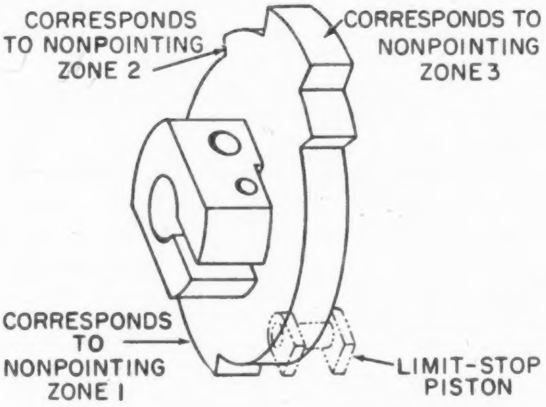
Position signals are produced by one set of cams and cam switches located in each receiver-regulator (fig. 6-37 train only). Each cam set consists of four cams rotated by B-end response gearing and four cam-actuated switches. Three cams indicate train position, three indicate elevation position, while the fourth cam in each set is a spare.

Three of the cams in each cam stock correspond to the three elevation levels and the three train positions shown in figure 6-36A. Whenever the gun enters one of these positions or levels, regardless of gun position or gun elevation, the cams for that zone open its associated switch to actuate the train and elevation limit-stop mechanism.

There are also a set of four position-plus-lead cams and cam switches in each receiver-regulator. Three of these cams indicate train or elevation position-plus-lead and the fourth cam indicates train direction forward or aft (train system only). The fourth elevation position-plus-lead cam is a spare.



A NONPOINTING ZONE PROTECTION


CORRESPONDS TO NONPOINTING ZONE 2
CORRESPONDS TO NONPOINTING ZONE 3
CORRESPONDS TO NONPOINTING ZONE 1
LIMIT-STOP PISTON

B LIMIT-STOP CAM AND PISTON

53.285

Figure 6-36.—Typical nonpointing zone system.

Each position plus lead cam set is rotated by B-end response gearing through the wobble gear of its respective system (fig. 6-37). The A-end input to the wobble gear rotates the position-plus-lead cams ahead of the true position of the mount in proportion to train velocity. The velocity lead causes the position-plus-lead switches to open before the mount actually reaches a nonpointing zone to allow time for gun mount deceleration.

LIMIT STOP ACTUATION (TRAIN)

The train limit-stop mechanism is actuated by deenergizing one of the two pointing-cutout solenoids (LCT-2 and LCT-3) in the train pointing cutout valve block (fig. 6-37).

Solenoid LCT-3 deenergizes to prevent training into nonpointing zone 3 whenever the gun is depressed below elevation level 3.

Note: The elevation cam switches control the deenergizing of the train pointing-cutout solenoids and the train cam switches control the elevation pointing-cutout solenoids.

Solenoid LCT-2 is deenergized under two separate conditions to prevent training into either nonpointing zone 1 or nonpointing zone 2. LCT-2 deenergizes for nonpointing zone 2 when the gun depresses into elevation level 2 when the mount is in the aft half of the training circle (from 180 degrees relative to ± 90 degrees relative, figure 6-36A). LCT-2 deenergizes for nonpointing zone 1 when the gun depresses into elevation level 1 while the mount is in the forward half of the training circle (from 0 degrees relative to ± 90 degrees relative, figure 6-36A).

When either of the train pointing cutout solenoids is deenergized, it shifts its associated control valve inside the train pointing-cutout valve block (fig. 6-37). Servo pressure (PA) passes through the lands of one of the solenoid valves to the bottom of one of the two train limit stop piston sections (UCT-2 or UCT-3). The larger area at the bottom of each piston allows PA pressure to shift one or both pistons up to engage the train limit stop cam (fig. 6-37).

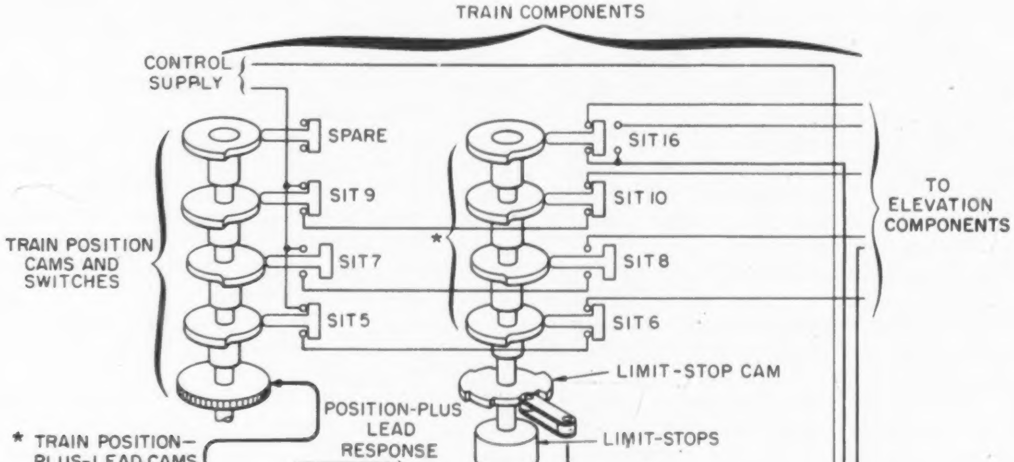
The train limit stop piston has two sections: UCT-2 and UCT-3. When PA is ported to either section of the piston, the piston moves up. When LCT-3 deenergizes, PA is ported to the bottom of UCT-3; when LCT-2 deenergizes, PA is ported to the bottom of UCT-2. Since section UCT-2 is longer than UCT-3, the limit-stop piston is shifted farther up when LCT-2 deenergizes. When the piston shifts up, it is in a position to engage the train limit stop cam for zone 1 or zone 2 (fig. 6-36B). The extension of the piston determines which raised area on the limit-stop cam will be engaged.

Train Limit Stop Cam

The train limit-stop cam is splined to the central shaft of the train limit-stop assembly below the position-plus-lead cam stack (fig. 6-33).

The edge of the limit-stop cam has three raised areas which correspond to the train positions of the nonpointing zones (fig. 6-36B). The area for zone 3 is the highest of the three; the areas for zones 1 and 2 are the same height, but are on opposite sides of the cam. When the limit-stop piston is extended, one of the three raised areas on the cam rotates against the piston, locking both the cam and the limit-stop shaft. The extension of the piston depends on which solenoid is deenergized. This, in turn, determines which raised area locks against the piston.

When the limit-stop shaft is locked, the train limit-stop mechanism prevents the mount from moving farther in train, (limit stop operation explained early in this chapter). Although gun laying signals are still applied to the train servo valve, the limit-stop mechanism overrides


TRAIN COMPONENTS
CONTROL SUPPLY
SPARE
SIT 16
SIT 9
SIT 10
TO ELEVATION COMPONENTS
TRAIN POSITION CAMS AND SWITCHES
*
SIT 7
SIT 8
SIT 5
SIT 6
LIMIT-STOP CAM
POSITION-PLUS LEAD RESPONSE
LIMIT-STOPS
* TRAIN POSITION-PLUS-LEAD CAMS AND SWITCHES
TRAIN WOBBLE GEAR
B-END GEAR REDUCTION
LIMIT-STOP PISTON
LIMIT-STOP LEVER
LCT2
UCT-2
LEAD
OVERRIDE DEVICE
LCT3
UCT3
POSITION RESPONSE
SERVO VALVE
PA PRESSURE
TRAIN CAB UNIT
ELECTRICAL
MECHANICAL
HYDRAULIC

53.286

Figure 6-37.—Pointing-cutout system functional diagram.

these signals to prevent the mount from training into the nonpointing zone. When the elevation system raises the gun out of the elevation level of the nonpointing zone, the zone solenoid is reenergized, the limit-stop piston is retracted, the train-limit-stop shaft is released, and the mount is free to train over the zone.

Combined Train and Elevation Cutout Operation

The pointing-cutout system deals with specific train and elevation angles. Any time the gun mount moves above, below, in, or out of these specific angles, cutout switches supply indications to the gun laying servo system.

Figure 6-38 shows the route of a loaded gun training right and depressing toward nonpointing zone 3 while tracking an air target. Circled numbers along the gun's route indicate that sequence of cutout operation.

Since the position-plus-lead (P + L) switches are the first switches to open and deenergize the nonpointing zone solenoids as the gun mount approaches a zone and the position switches are the last to close as the gun travels away from the zone, figure 6-38 shows only the opening points of the P + L switches and the closing points of the position switches.

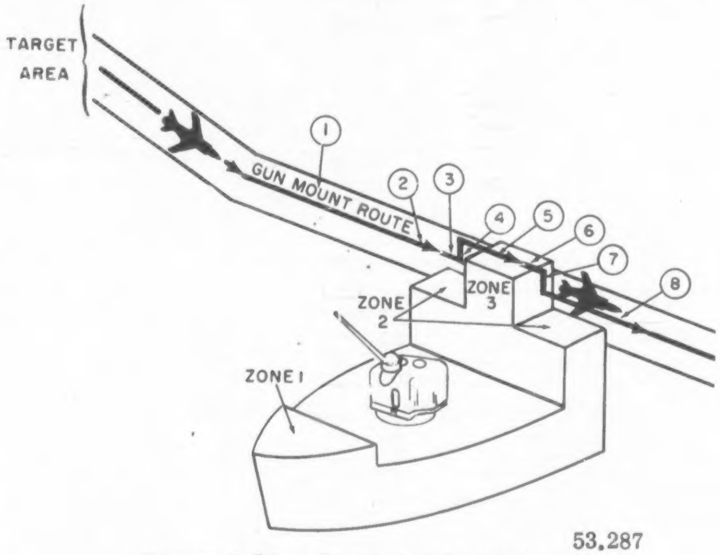
At point 1, the elevation P + L switch for nonpointing zone 3 opens. This action deenergizes train zone 3 solenoid LCT-3 (fig. 6-37) causing UCT-3 to extend and drive the limit-stop piston to a position where it contacts the zone 3 area of the train limit-stop cam. The limit stop piston, however, does not halt the stop cam until the zone 3 area of the limit stop cam rotates into a position to contact it. The deenergizing of LCT-3 supplies the train system with an indication that the gun has depressed below the zone 3 elevation limit.

At point 2, the train P + L switch for zone 3 opens causing the elevation limit-stop system to take control. After a short transition period required to shift servo control from the elevation amplifier to the elevation limit-stop system, the launcher stops depressing and starts elevating under limit-stop control.

At point 3, the train nonpointing zone cam contacts the limit stop piston, supplying a stop order to the train limit-stop system. Control of the train power drives passes from the train amplifier to the train limit-stop system, causing the train power drive to decelerate and stop under limit-stop control.

At point 4, the launcher has stopped training but continues elevating through the elevation limit-stop system.

At point 5, the elevation zone 3 position switch closes, energizing LCT-3 (elevation above zone 3) causing UCT-3 to retract. Since train stop cam movement is no longer restricted and a right train order is in effect, the launcher begins to train across the top of zone 3.



53.287
Figure 6-38. — Sequence of cutout operation.

At point 6, the gun cannot follow the depression order from the amplifier because the gun mount is not past zone 3 and the elevation limit-stop system holds the gun at a fixed elevation above zone 3.

At point 7, the zone 3 train position switch closes and the elevation limit-stop piston retracts. This action frees the elevation limit-stop rack and the gun begins to synchronize with the depression order from the elevation amplifier.

At point 8, the train and elevation orders are synchronized and the gun mount can resume tracking the target.

Order Sources

Order sources vary according to the tactical situation. These sources are: remote, local, test, and one man control (OMC).

REMOTE.—Signals originating at the remote source in a fire control system (FCS) which provide the order signals for mount movement.

LOCAL.—A local (fixed) director supplies train and elevation orders when the mount is in either local or test. The train and elevation systems are each served by a 1XCT and a 36XCT. Manual operated controls located on the front of a control panel drive the rotors of the synchro transformers. Each control (train and elevation) is geared to a set of transformers and indicating dials. The local mode of operation is used for test, maintenance, and emergency operation.

TEST.—When the mount is test control, the mount captain can use the external (dummy) director to supply dynamic test signals to either the train servo or the elevation servo. Under test conditions, an external director can be connected into the circuitry as an order source.

OMC.—The one man control unit generates positioning signals from a station in the gun house. Velocity information from the OMC is applied to the amplifier as an operator manipulates the handgrips to position the mount in the same manner as explained for Mods 1 through 8 (fig. 6-24).

POWER-OFF BRAKE

The Mk 42 Mod 9 gun mount has power-off brakes which serve to (1) stop the gun when power is lost, (2) secure the equipment against pitch and roll of the ship when the system is inactive, and (3) provide a means through which to train and elevate or depress the mount with an air motor during power off operation for maintenance, emergency operation, or installation procedures. Figure 6-39 shows the important parts of the power-off brake. The brake shaft extends out of the brake housing and connects to the equipment it controls. The friction disks mesh alternately with the brake shaft and the brake housing. Springs force the pressure plate against the friction disks. The connecting rod joins the piston to the pressure plate.

Power Operation

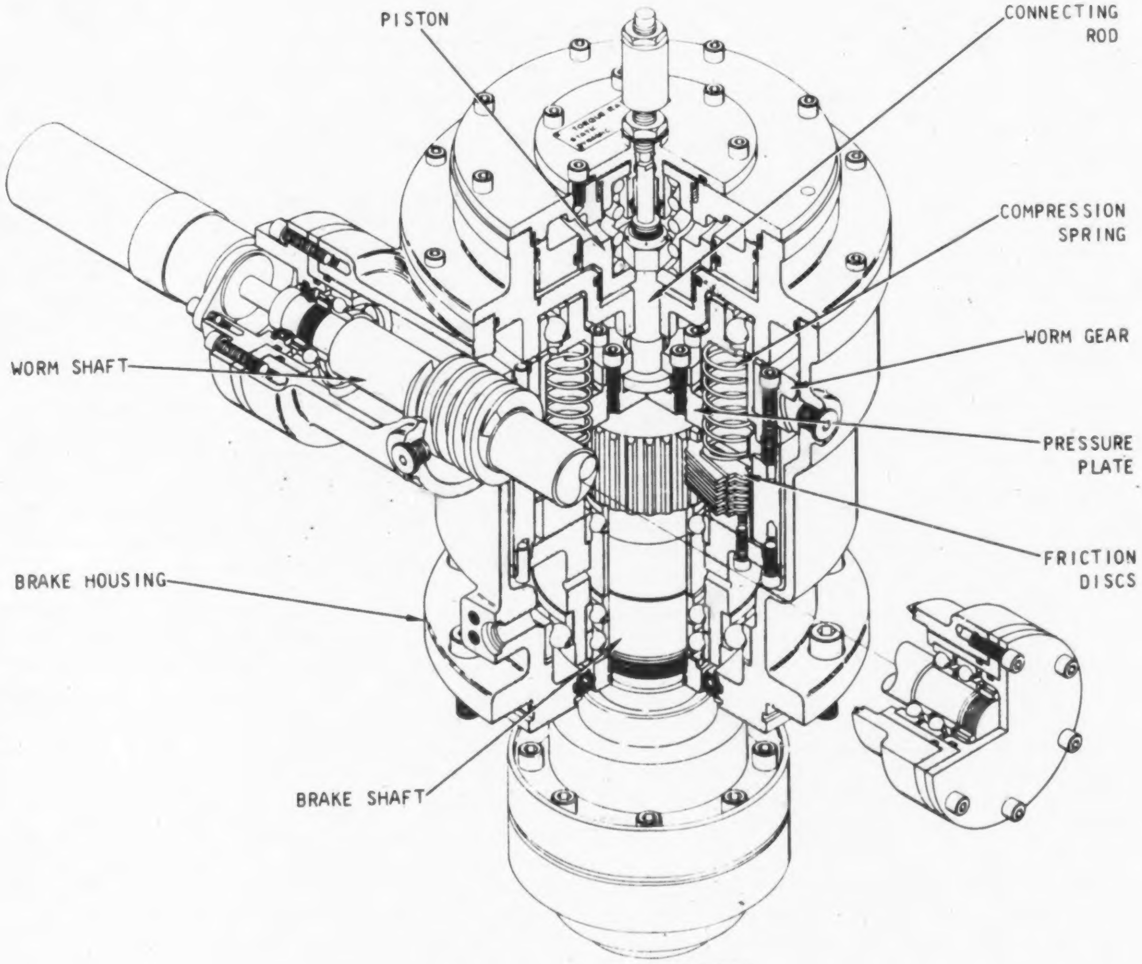
Hydraulic pressure releases the power-off brake and spring pressure sets it. Since the operation of the train and elevation power-off brake is identical, only the train brake is discussed. When the train system is activated, the power-off brake is released by hydraulic pressure and the mount is free to turn. When the train brake solenoid LHT-1-LC1 is energized (figure 6-40A), it shifts brake release valve UVT20 down to port PA to the left side of brake release piston UCT6. When piston UCT6 is shifted to the right, the connecting rod attached to the pressure plate pulls the plate away from the friction disks compressing the compression springs. The brake shaft is then in the disengaged position and can turn easily with the rotation of the equipment it controls.

When the system is shut down or power is lost during normal operations, LCT1-LC1 is deenergized. Piston UVT20 shifts up and closes the PA port to the brake piston (fig. 6-40B). The compression springs force the pressure plate to contact the disks and the disks come in hard contact with each other. The brake shaft is then connected to the brake housing through the friction disks and worm gear (fig. 6-39).

When the power-off brake is stopping a piece of equipment, the worm gear transmits force to the worm shaft. However, the pitch of the worm shaft is too low to result in a transfer of motion from the worm gear to the worm shaft. The worm shaft is coupled directly to the air motor, figure 6-41, and rotates in the same direction as the air motor.

Air Motor

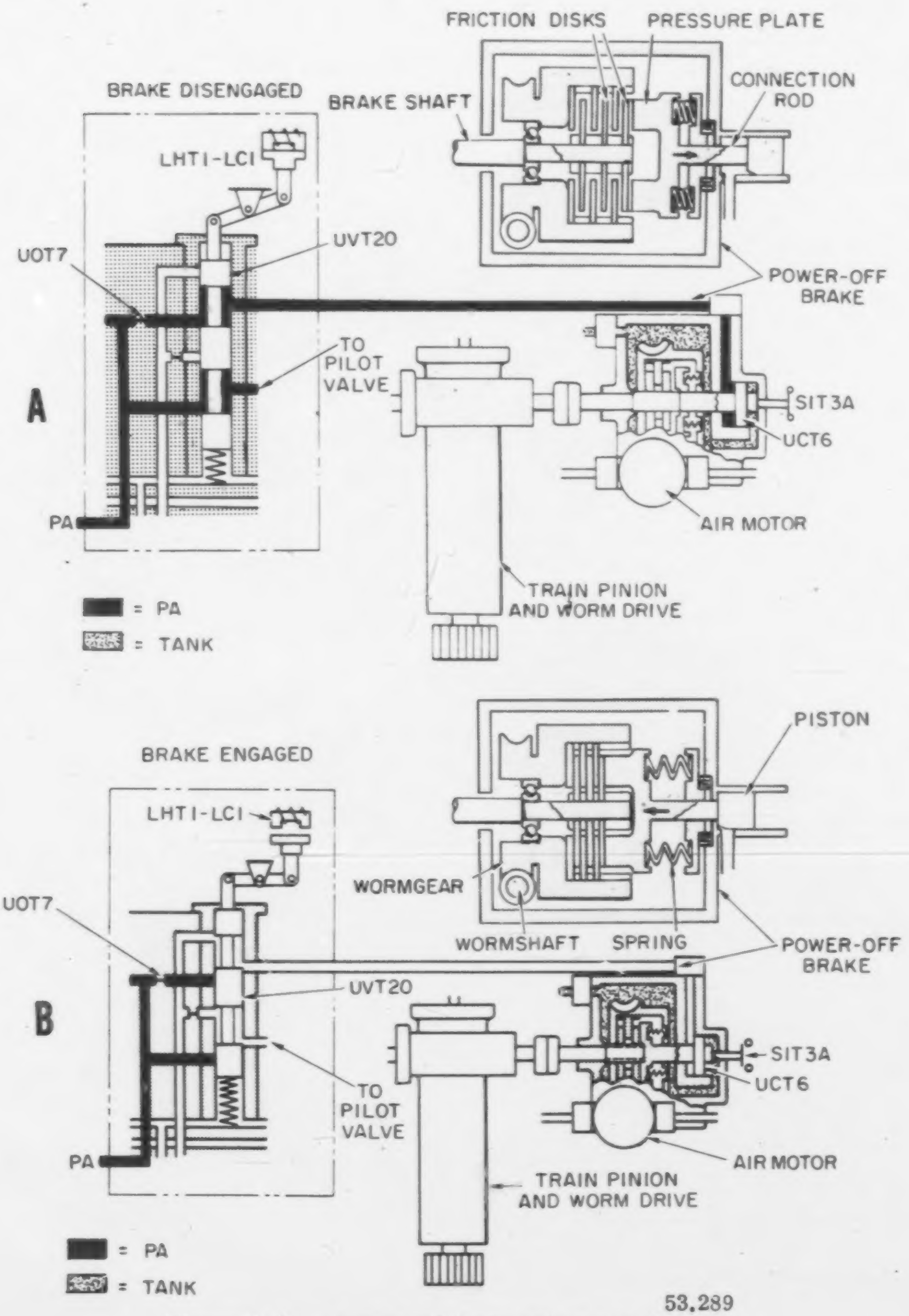
Air motor operation is not possible if the brake is disengaged, because the friction disks



53.288
Figure 6-39.—Power-off brake.

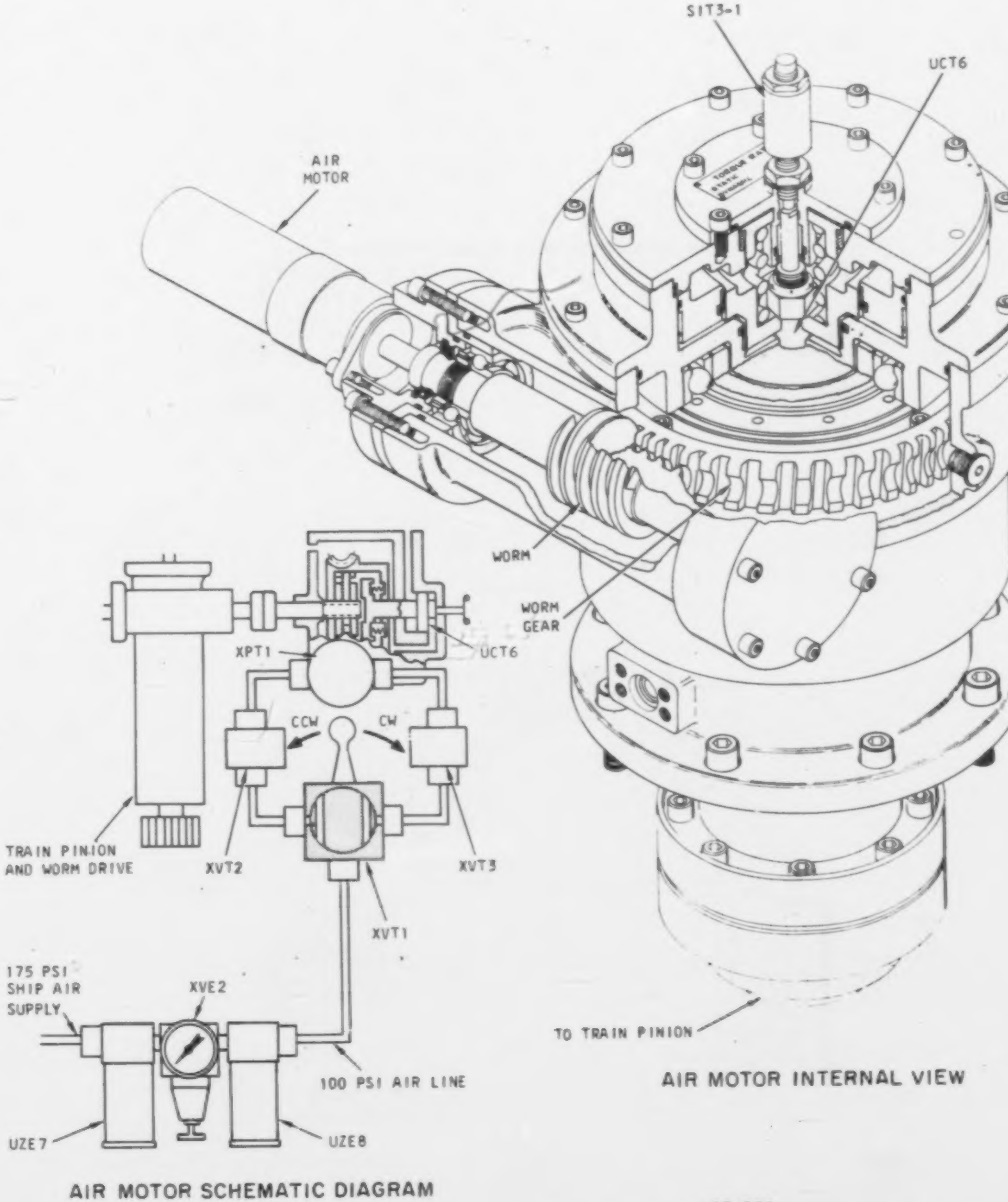
are not in positive contact with each other and the brake shaft turns freely without exerting force in the worm gear. In the engaged position, the power-off brake transmits rotation from the air motor to the equipment associated with the brake (train or elevation).

To train the mount, air is ported through manual pneumatic control valve XVT1 (fig. 6-41) and through either train limit pneumatic cutoff valve XVT2 or XVT3 to air motor XPT1. Spring-loaded valve XVT1 can be in one of three positions. Unless manually positioned otherwise, the valve is at neutral and no air pressure is applied to the motor. With the handle of XVT1 held in the clockwise position, air is ported to the right side of XVT1 through XVT3 to the air motor causing the motor to turn clockwise. Since the output shaft of the motor is splined to the worm shaft, the worm shaft turns the worm gear which drives the brake shaft (fig. 6-41). The brake shaft drives the train pinion to train the mount clockwise. For counterclockwise train, the handle of XVT1 is held to the left, the counterclockwise position.


FRICTION DISKS
PRESSURE PLATE
BRAKE DISENGAGED
BRAKE SHAFT
CONNECTION ROD
LHT1-LC1
UVT20
UOT7
POWER-OFF BRAKE
TO PILOT VALVE
A
SIT3A
UCT6
AIR MOTOR
PA
TRAIN PINION AND WORM DRIVE
= PA
= TANK
PISTON
BRAKE ENGAGED
LHT1-LC1
WORMGEAR
UOT7
WORMSHAFT
SPRING
POWER-OFF BRAKE
UVT20
B
SIT3A
UCT6
TO PILOT VALVE
AIR MOTOR
PA
TRAIN PINION AND WORM DRIVE
= PA
= TANK

53.289

Figure 6-40.—Power-off brake schematic diagram.


SIT3-1
UCT6
AIR MOTOR
WORM
WORM GEAR
XPT1
UCT6
CCW
CW
TRAIN PINION AND WORM DRIVE
XVT2
XVT3
XVT1
175 PSI SHIP AIR SUPPLY
XVE2
100 PSI AIR LINE
UZE7
UZE8
TO TRAIN PINION
AIR MOTOR INTERNAL VIEW
AIR MOTOR SCHEMATIC DIAGRAM

53.290

Figure 6-41.—Train power-off drive air motor.

SAFETY

Practical safety features are built into Navy equipment to eliminate potential hazards to personnel. Since familiarity with equipment leads to carelessness, observation of all safety precautions and rules is mandatory.

OP 3347, United States Ordnance Safety Precautions, is now the official publication for ordnance safety precautions. This publication supersedes OPNAV 34P1, Chapter 20, and is applicable to both sea and shore establishments of the Navy.

MOVING EQUIPMENT

All personnel taking part in or observing operation of power equipment shall remain alert, keep clear of moving parts, and be thoroughly familiar with the safety precautions applicable to that equipment. At no time will sky larking be allowed in the vicinity of operating power equipment.

When making phase balance, or feedback adjustments, to servo amplifiers or when adjusting receiver regulators, the following warning should be emphasized.

The gun mount and/or gun barrel may drift during alinement or adjustment of power drives. Sound the train warning bell and ensure that the area around the mount is clear.

HYDRAULIC EQUIPMENT

Hydraulic systems operate under hydraulic pressures ranging from approximately 100 psi to 2,000 psi. If not properly respected, these pressures could present hazards to personnel. The following safety rules should be observed:

Never disconnect hydraulic lines or disassemble hydraulic equipment when the hydraulic system power motor is running. In some accumulator systems, system pressures can remain within the system for hours, and even days, after the power motor has been stopped. Never disconnect hydraulic lines or disassemble hydraulic equipment until the accumulators have been manually dumped to tank.

Only competent qualified personnel will manually actuate switches, relays, solenoids, or valves on hydraulic systems under pressure. Even competent qualified personnel should exercise the utmost care with the understanding that their actions may bypass built-in safety features of the system.

All hydraulic leaks should be reported immediately and corrected at the first opportunity. A small leak in a high pressure system appears as a fine spray or mist which, in some fluids, could be ignited by a spark, thereby causing an explosion.

ELECTRICAL EQUIPMENT

Since weapon systems electrical equipment employs voltages up to 440 volts, which are extremely dangerous, only authorized personnel who have been duly assigned for weapon systems upkeep shall work on this equipment.

Whenever possible, the main supply and power switches shall be turned off and tagged before an electrical circuit is checked or overhauled. When electrical equipment has to be serviced or adjusted with the power covers removed and the circuits energized, the following safety rules shall be observed:

Always work in the presence or with the assistance of another person who is capable of rendering first aid.

Remove rings, wrist watches, bracelets, and other metal items.

Do not change fuses or lamps in power panels when the electrical circuits are energized.

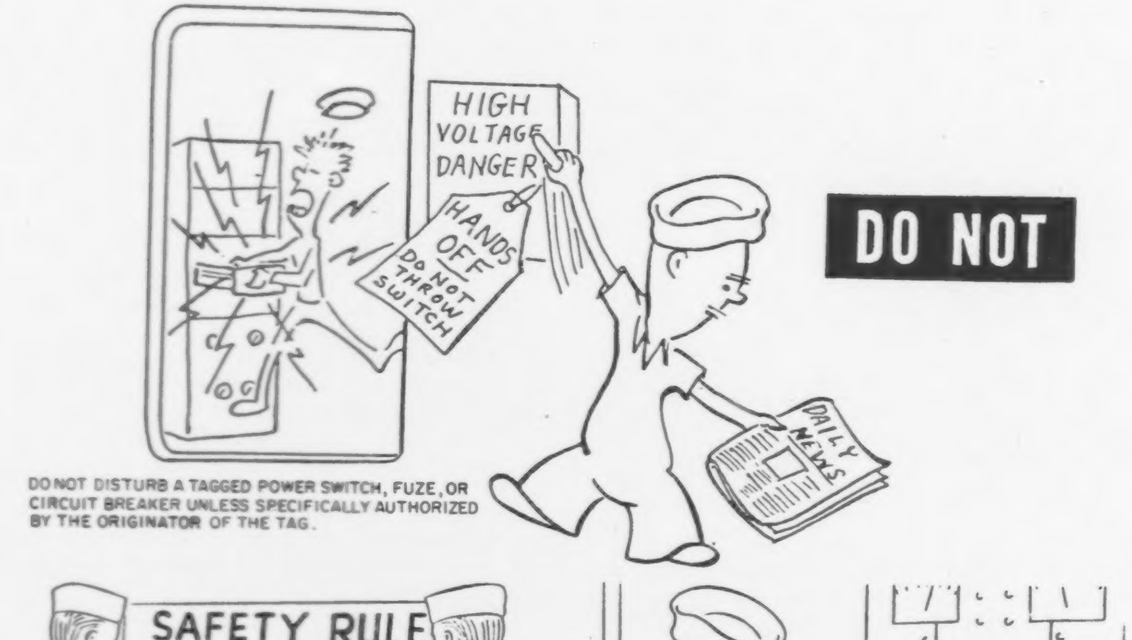
When making adjustments, use only tools with adequately insulated handles.

Keep hands, clothes and shoes dry.

Ensure good insulation from ground with some suitable nonconducting material such as dry wood, several layers of dry canvas, or rubber mats of approved construction.

Under certain conditions, due to capacitors that retain their charges, dangerous voltage potentials may still exist in circuits even after the circuits have been deenergized. These circuits can be discharged by grounding. Remember always check an electrical circuit with a voltmeter to ensure that the circuit is open.

Never remove, short circuit, or tamper with safety interlocks without specific authority. Periodic tests and inspections of these devices must


HIGH
VOLTAGE
DANGER
HANDS OFF
DO NOT THROW SWITCH
DAILY NEWS
SAFETY RULE
BABES
HIGH VOLTAGE

DO NOT

DO NOT DISTURB A TAGGED POWER SWITCH, FUZE, OR CIRCUIT BREAKER UNLESS SPECIFICALLY AUTHORIZED BY THE ORIGINATOR OF THE TAG.

DO NOT BEGIN A TASK UNTIL ALL PROCEDURES INVOLVED AND APPLICABLE SAFETY PRECAUTIONS ARE KNOWN AND UNDERSTOOD.

DO NOT DEPEND ON THE EQUIPMENT SWITCH TO REMOVE POWER FROM EVERY PART OF THE EQUIPMENT.

40.67(53C)
Figure 6-42.—Safety depends on you.

be made to ensure that they are operating correctly.

Electrical safety precautions shall be posted on or near each group of electrical or electronic equipment. Specific safety precautions pertaining to electrical or electronic equipment are contained in NAVSHIPS 250-000, Chapter 9670.

SAFETY DEPENDS ON YOU

(Figure 6-42 illustrates the DO NOTS).

CHAPTER 7

FIRE CONTROL

A hundred and fifty years ago, the Gunner's Mate was a jack of all trades relating to armament. Any competent Gunner's Mate was expected to know how to load, aim, and fire any gun, from small arms to hundred-pounder cannon and larger. He was expected to know how to make up mines (then called torpedoes) and other charges, and how to handle black powder. And that was about all. Of course, he was also expected to be a competent seaman, but so far as armament goes, he didn't have to know any more because there just wasn't much more to know.

Don't get the idea that the old time Gunner's Mate had an easy job. He had arduous; dangerous work to do, and a good deal of it, without the help of the multitude of laborsaving and lifesaving devices that you have at your disposal now. But that doesn't change the fundamental point here, which is that a hundred and fifty years ago it was possible for one man to master, without mental strain, ALL the skills that related to the efficient operation and maintenance of the armament of the time.

As naval armament became more specialized and complex, the body of skills and knowledge that the Gunner's Mate was expected to master became correspondingly specialized and complex, and other specialists like FTs, TMs, AOs, and MNs had to take over part of what had at one time been exclusively Gunner's Mate's work. But today the Gunner's Mate, though he too has specialized, is still expected to be something of an expert on armament. Much of this book is devoted to aspects of armament other than guns, and to the study of techniques and gear not narrowly concerned with what is within the confines of the gun mount shield.

Fire control is certainly no novelty to you. Nobody has to remind you that the Fire Control Technician's work is as immediately essential to the effectiveness of your ship's armament as is yours. So it isn't surprising that the Qualifications for Advancement in Rating state that you are expected to master certain skills that you ordinarily associate with the Fire Control Technician. This chapter is intended to give you the background that you will need to fulfill this part of your job. It will also serve as a convenient review of the principles of fire control with which you are already acquainted from earlier courses in this series, as well as a basis for study of chapter 8 on battery alignment.

The first section of this chapter describes the concept of a ship's weapon system. The second section is devoted to the discussion of two types of gunfire control systems, the linear-rate system and the relative-rate system. The types of fire control equipment used with each type system will also be explained. In the last section ASW fire control systems used against submerged submarines are described.

WEAPONS SYSTEM CONCEPT

Fire control is problem-solving, the problem of destroying a target with ship's armament. Solutions must be found for the three types of targets: surface, air and underwater targets. The effective use of any weapon system requires that a destructive device be delivered to a target. The destructive device (weapon) could be a guided missile, gun projectile, rocket, torpedo, or depth charge.

To deliver the weapon accurately, we must know both the location and the velocity of the target. Many air targets now travel faster than sound and must be engaged at great distances. Against such targets a weapon is most effective when it is used as part of a ship's weapon system. A weapon system is the combination of weapons, each classified by its tactical purpose, and the fire control equipment used with each weapon or multiple of weapons to damage or destroy a selected target.

A weapon system includes:

1. Units that detect, locate, and identify the target
2. Units that direct or aim a delivery unit
3. Units that deliver or initiate delivery of the weapon to the target
4. Units termed weapons that destroy the target when in contact with it or near it

Figure 7-1 represents a typical shipboard weapons system. The equipments making up each of the four categories of functional components are enclosed in separate blocks. The following headings take up the purpose of the four groups and introduce some of the equipment used to solve the fire control problem.

DETECTING UNITS

The first steps in using a weapon system to solve the fire control problem are to detect, locate, and identify the target. Initial contact with a surface or air target may be visual, or it may be made by radar. It is difficult to detect a target visually at long range, or even at short range when visibility is poor. For that reason, targets are usually detected by search radar. Search radars, as you know, keep a large volume of space around your ship under continuous watch. They give the ship fairly accurate information about the target's position, even when the target is hidden by fog or darkness. To determine a target's position, we must know its range, its direction from the ship, and, for an air target, its elevation. Radar gives all three of these coordinates. (Radar has certain disadvantages, too. For example, it can be detected by an enemy at about 1.5 times the range at which it can pick up an enemy target.)

Optical devices are used as a source of information on slow-moving targets at relatively short range. They are useless against missiles or jet aircraft, which must be engaged while they are still beyond the range of optical instruments.

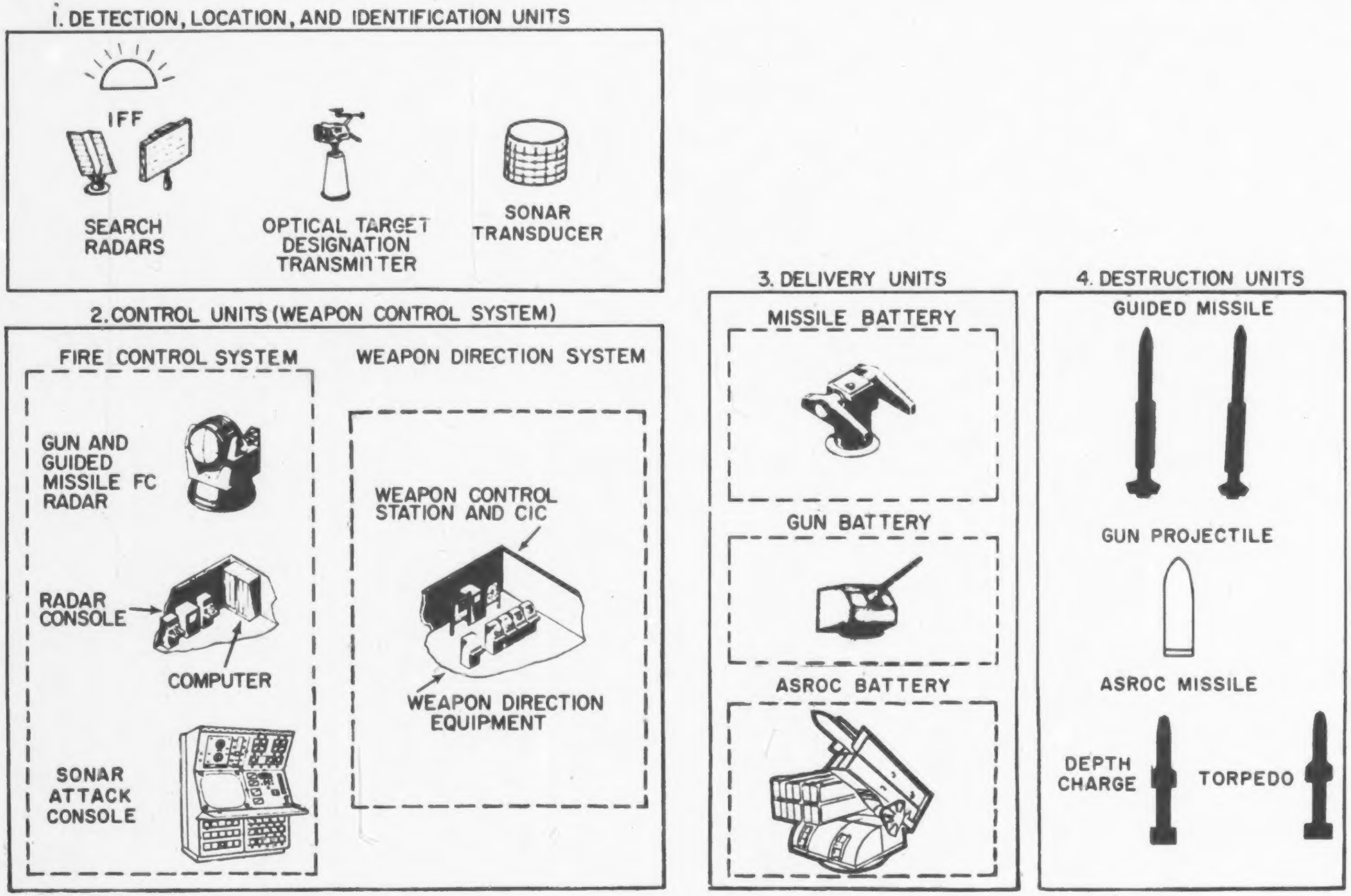
After we have detected and located a target, we must identify it. How can we identify a target that may be several hundred miles from our ship? The answer lies in a device called IFF (Identification, Friend or Foe). Radar alone cannot tell the difference between a friendly or enemy target. But the IFF equipment can challenge an unidentified target, and determine from the answer whether the target is friendly. The equipment consists of two major units—the challenging unit which asks the question (Friend or Foe?) and the transponder which answers the question. IFF equipment is used in conjunction with search radar and, sometimes, fire control radar. Briefly, this is how it works. To challenge a target, you press a switch attached to the radar. The IFF transmitter will then send out a pulse of low power radio energy toward the target. If the target is friendly, it will carry a transponder, which consists of a receiver and a transmitter. When the receiver picks up a challenge, it causes the transmitter to send out an answering pulse or pulses. The answer is usually a coded message. It is picked up by the challenging unit's receiver and sent to the indicator of the search radar.

The underwater problem is similar to the air problem, but upside down, with the attacking ship moving in a horizontal plane above the target. The motions of own ship and target are resolved into horizontal components in and across the sonar bearing or "line of sound" (no line of sight in this problem) to compute the attack course, the time of fire, and (for thrown weapons) the range and bearing of projection.

To attack a submerged submarine, it is first necessary to detect it, establish its location and its rate of movement in bearing and depth, and then solve this fire control problem to predict the submarine's future location so that an antisubmarine warfare (ASW) weapon can be used against it.

The blind time, time elapsed between firing and predicted impact of ASW weapons, is much greater than that for gun fire control. Therefore, ASW weapons are designed to be effective over a larger area than, for instance, gunfire at the same range.

The chief method of detection and location of submerged submarines by surface craft is by using sound, which travels underwater about four times faster than it does in air. Sonar is the primary method of sound detection now used on most surface ships. It is known as scanning or azimuth search sonar. With each outgoing burst of sound, scanning sonar transmits the sound pulse in all directions simultaneously and picks up echoes from any or all points. In addition, scanning sonar offers both video and audio presentation of target information. A transducer, usually located in the forward section of the keel of the ASW vessel, is used to send out sound pulses and also acts as the receiver for echo pulses from a detected submarine.


1. DETECTION, LOCATION, AND IDENTIFICATION UNITS
IFF
SEARCH RADARS
OPTICAL TARGET DESIGNATION TRANSMITTER
SONAR TRANSDUCER
2. CONTROL UNITS (WEAPON CONTROL SYSTEM)
FIRE CONTROL SYSTEM
GUN AND GUIDED MISSILE FC RADAR
RADAR CONSOLE
COMPUTER
SONAR ATTACK CONSOLE
WEAPON DIRECTION SYSTEM
WEAPON CONTROL STATION AND CIC
WEAPON DIRECTION EQUIPMENT
3. DELIVERY UNITS
MISSILE BATTERY
GUN BATTERY
ASROC BATTERY
4. DESTRUCTION UNITS
GUIDED MISSILE
GUN PROJECTILE
ASROC MISSILE
DEPTH CHARGE
TORPEDO

12.41

Figure 7-1.—Weapons System concept.

CONTROL UNITS

Control units in a weapon system develop, compute, relay, and introduce data into a delivery unit, a weapon, or both. They direct, control, or guide the weapon (destructive device) to the target, and cause it to function in the desired way. These units form the heart of the weapon system.

Types of Control Units

DATA TRANSMISSION SYSTEMS send target position information developed by the detecting units to the rest of the weapon system, and convey other data among the components of the weapon system. Examples are synchro, resolver, and potentiomenter circuits.

COMPUTER DEVICES.—process the input data from the detecting units and other sources, and put out the aiming and program instructions that cause the weapon to reach its target. Examples are rangekeepers and computers.

DISPLAY UNITS.—display information at various locations on the ship. These are generally electronic, electromechanical, or optical devices.

DIRECTING DEVICES.—with the aid of detecting devices, establish target location. Directing devices can also function to directly or indirectly control missile flight. Examples are gun and missile directors, and radar sets.

REFERENCE DEVICES.—such as stable elements establish reference planes and lines to stabilize lines of fire, lines of sight, and other references. These units usually are gyroscopically controlled.

DELIVERY UNITS

Broadly speaking, delivery units launch or project destructive units toward the target. Examples are guns, missile and rocket launchers, torpedo tubes, and depth charge projectors. Don't think of these devices as weapons. The term WEAPON is properly applied to the destructive unit that is launched or projected. Thus a guided missile launcher is not, strictly speaking, a weapon; the missile itself is the weapon.

To be effectively employed against their targets, all weapons must either be aimed at their targets or be programmed during flight; they may require both aiming and programming. Programming is the process of setting automatic equipment to perform operations in a predetermined step-by-step manner. Aiming and programming are done at or before the time of launching, either by or through the delivery device. This function is characteristic of all delivery devices, even the simplest. Aiming the destructive device (weapon) at the target may be done simply by positioning the delivery device (a gun barrel or launcher guide arm, for example). Or it may be done without aiming the delivery device, by placing program instructions in the weapon. Some missiles are programmed to start searching for the target after the launching phase is over. Examples of other programmed functions that could be performed in the weapon are ignition of propulsion units and arming of the warhead after a designated number of seconds in flight.

Types of Delivery Devices

GUNS. — which provide all the propulsion energy to their projectiles, direct (aim) the projectiles by positioning the gun barrels.

MISSILE LAUNCHERS.—retain and position missiles during the initial part of the launching phase and, by means of attachments to the launcher, feed steering, vertical reference, and program information into the missile up to the instant of launch. Of course there are other types of delivery devices, such as torpedo tubes, depth charge and thrown weapon projectors, and rocket launchers.

Destructive Units

The end purpose of detection units, delivery units, and control units is to cause the destruction unit to intercept or pass near the target. It is then the function of the destruction unit to destroy or inflict maximum damage on the target. Except for projectiles used in small arms, and some of those used in calibers up to 40-mm, weapons used in combat are loaded with explosives, and equipped with devices to set off their explosion at the proper time. For some weapons, the proper time is the instant the weapon makes physical contact with the target. For those designed to penetrate targets protected by armor or concrete, the proper time is after penetration. Still others are intended to explode when they reach the vicinity of the target.

Basic Weapon Components

All weapons have these components:

1. A CONTAINER or BODY which houses the internal components. The body may have such other functions as piercing armor, breaking up into high velocity fragments when the weapon explodes, or improving the weapon's ballistic characteristics by means of fins or streamlining.
2. A DETONATING DEVICE (called a fuze, exploder, detonator, etc.) which initiates explosion at the proper time, and includes safety devices to prevent premature explosion.
3. A PAYLOAD which is the "reason for being" of the weapon. The payload usually consists of high explosive or nuclear material.

Weapons of some types have their own propulsion systems. The outstanding examples are guided missiles, torpedoes, and rockets. With the exception of rockets, weapons that have a propulsion system also contain guidance and control systems.

To summarize the weapon system concept, we can say that any weapon system contains four major functional components which are interrelated to make up the system as a whole.

We can also say that a ship's weapon system is made up of several different types of weapons and their systems. In figure 7-1, the ship's weapon system consists of three different systems: a missile weapon system, a gun weapon system and an ASW weapon system.

GUN WEAPON SYSTEM

Functionally a gun weapon system includes the following elements:

1. A fire control system
2. One or more gun mounts organized as a BATTERY
3. Ammunition supply arrangements

Since it is inherently flexible both in function and in the equipment that goes to make it up, a gun weapon system is not invariably composed of the same elements—in fact, a combination of the elements that make up a system may vary during a single exercise or battle action. However, a given combination is generally recognized as best—this is the PRIMARY arrangement—and others (SECONDARY arrangements) may be substituted if required by battle casualties or for training purposes. This chapter will concentrate on the preferred combinations that make up the primary systems.

There are several ways to classify gun weapon systems. The simplest and probably the best method is according to their service application as follows:

1. SURFACE BATTERY—a battery that is designed primarily to combat surface targets (including shore-bombardment or gunfire support). This battery, sometimes called single purpose, is comprised of 6" or 8" turrets mounted on cruisers. (Turrets can be used against air targets, but this is not their primary application.)
2. DUAL PURPOSE BATTERY — a battery that is designed to combat both air and surface targets (including gunfire support). Dual purpose batteries are 5" guns only. Dual purpose relates not so much to the 5" gun's versatility, as it does to the dual-computing devices and methods in the fire control system.
3. AA BATTERY—a battery that is designed primarily to combat air targets. This battery normally has 3" guns. The 3" gun can also be used against surface targets, and for "direct fire" missions in gunfire support.

FIRE CONTROL IN GUN WEAPON SYSTEMS

In any weapon system the fire control problem is essentially that of getting the weapon to hit the target and explode or at least, to explode when the target and weapon approach close enough for maximum damaging effect. In gun weapon systems the problem is to lay (aim) the gun in such a way that the projectile will hit or approach close to the target. In some other types of weapon systems the weapon is self-propelled and contains guidance equipment so that it is capable of homing on the target (i.e., it can detect the target and follow it, ultimately catching up with it), or other guidance methods may be available. This is not true of gun weapon systems. Once the projectile has left the gun muzzle, nothing further can be done to affect its course. The gun's fire control problem ideally must be solved before the gun fires.

In a gun fire control weapon system the two problems in shipboard fire control are surface targets and air targets. In the surface problem, we take estimated values of target course and speed, measured range, relative bearing, own ship's course and speed, and certain other factors such as wind direction and speed. We then resolve ship and target motion into linear rates in and about the line of sight, and compute the predicted future position of the target. Then we compute necessary ballistic corrections and work out gun orders which will direct projectiles fired from the guns onto the target.

The air problem is similar to the surface problem but, because we are firing at air targets, we must measure target elevation—the vertical angle between the line of sight and the horizontal—as an additional input.

These brief summaries omit the refinements, but they do give the general idea of what is done in the solution of each problem. To understand more clearly just how the fire control problem is solved in each case, we should know something about the gear used. You have already been introduced to most of it in earlier courses in this series; here we shall briefly review what you already know, and take up in some further detail the functions of each type in dealing with the fire control problem.

FIRE CONTROL EQUIPMENT

The types of fire control equipment we will take up here include the director, computer, stable element, and radar.

The gunfire control equipment listed above will be discussed briefly in this section as separate units. Later in this chapter, we will tie them together into a fire control system.

Director

In general, we can say that a director is a device used to locate a target's position in terms of range, bearing and, in a dual-purpose or AA director, elevation. These are the basic data necessary for computing gun orders.

The methods by which the director measures and transmits these values will vary according to the type of system in which the director is used.

In some instances, the director will contain the devices necessary to translate target range, and target movements in train and elevation, into terms of relative motion to predict the target's future position; and it will send gun orders to the gun for proper lead angle. Other directors are used to locate a target in terms of range, bearing, and elevation, and send these values continuously to a computer which solves the relative motion problem and issues gun orders.

Later in this chapter, we will discuss the various methods of director operation as they apply to specific systems. To explain a typical director we have chosen the Mk 37, which is used extensively in the fleet today.

The Mk 37 director, illustrated in figure 7-2, is normally manned by five men—pointer, trainer, radar operator, rangefinder operator, and control officer. The director can be controlled in three ways: (1) manually by handwheels, (2) local control, in which the power drives are controlled by signals originating at the director, and (3) automatically, when the director is driven to stay on target by orders returning from the associated computer.

The director personnel may acquire the target by visual observation or via the target designation system (TDS). Once acquired, the target can be tracked by telescopes or radar.

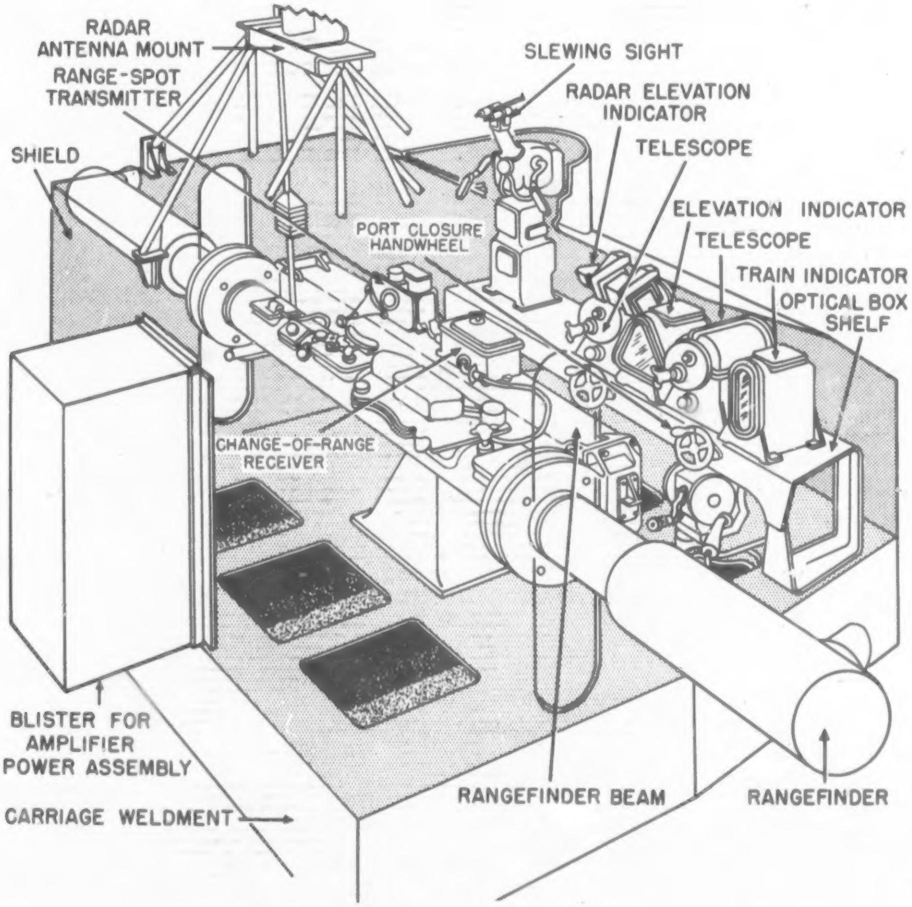
As the director tracks the target, bearing (train) and elevation are automatically sent to the computer by a synchro transmission system. Range, measured either by radar or rangefinder, is also sent automatically to the computer.

Computer

The computer is the thinking component of the fire control system. The Mk 1A computer, shown without its cover in figure 7-3 is placed figuratively between the director and the gun mounts. At first glance, the computer looks like a chaotic maze of objects. Actually, it is an orderly collection of connected basic mechanisms. The mechanisms themselves—component solvers, multipliers, differentials, and so on—do the computing. The thousands of gears and shafts merely transmit motion from one mechanism to another, so that all the mechanisms will work together as a network.

The computer receives the basic data of bearing, elevation, and range from the director. With the help of additional information such as level and crosslevel from the stable element, the computer solves the fire control problem. It sends gun orders by synchro transmission to the indicator regulators at the guns.

At the same time, the computer feeds rates of target motion (with the value of level from the stable element figured in) back to the director to keep the lines of sight (optics and radar) on the target.


RADAR ANTENNA MOUNT
RANGE-SPOT TRANSMITTER
SHIELD
SLEWING SIGHT
RADAR ELEVATION INDICATOR
TELESCOPE
ELEVATION INDICATOR
TELESCOPE
TRAIN INDICATOR
OPTICAL BOX SHELF
PORT CLOSURE HANDWHEEL
CHANGE-OF-RANGE RECEIVER
BLISTER FOR AMPLIFIER POWER ASSEMBLY
CARRIAGE WELDMENT
RANGEFINDER BEAM
RANGEFINDER

53.104
Figure 7-2.—Mk 37 director (interior).

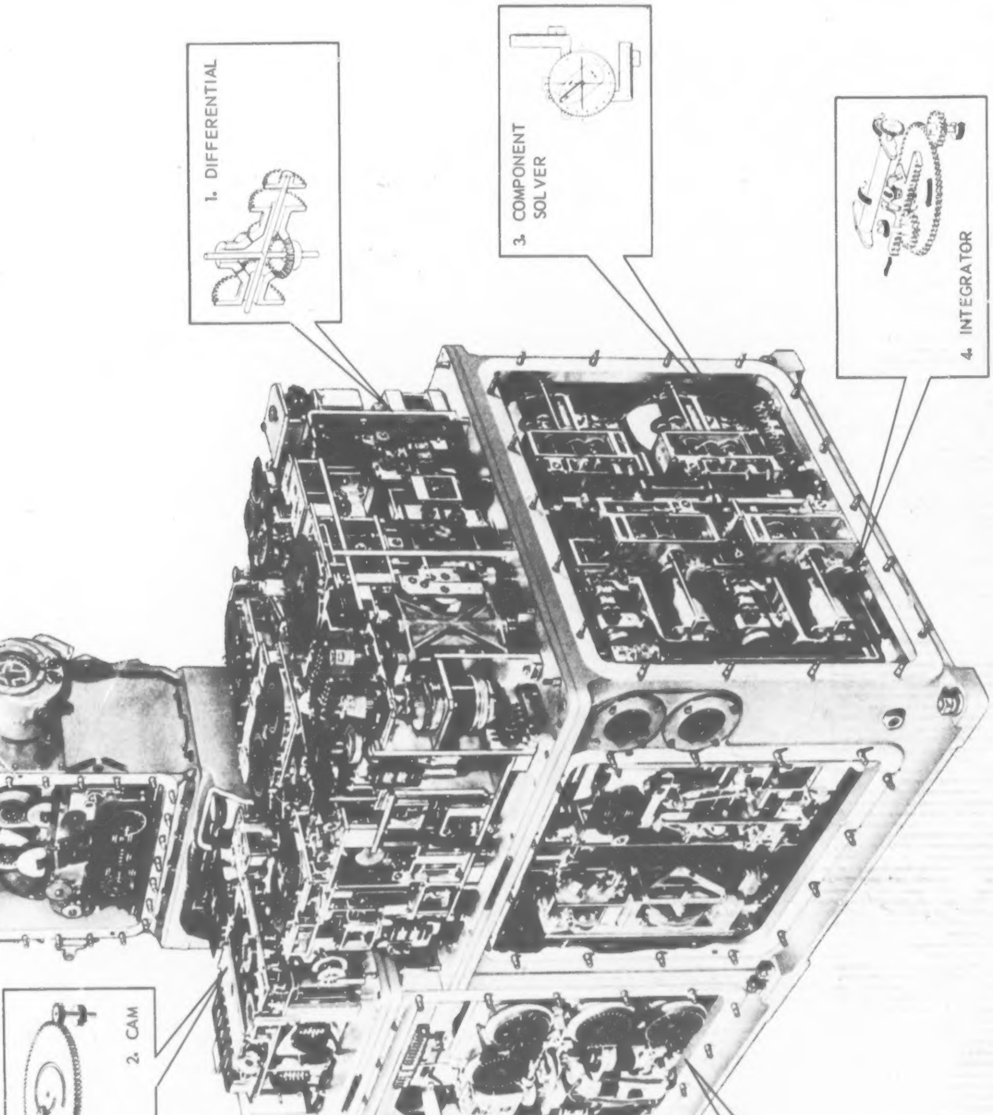
Stable Element

The stable element (fig. 7-4) is a gyroscopic device with the principal function of maintaining a true horizontal under all conditions of roll, pitch, and other changes in the ship's attitude, and transmitting the amount of deviation from the horizontal into the system. Both level and crosslevel are fed to the computer.

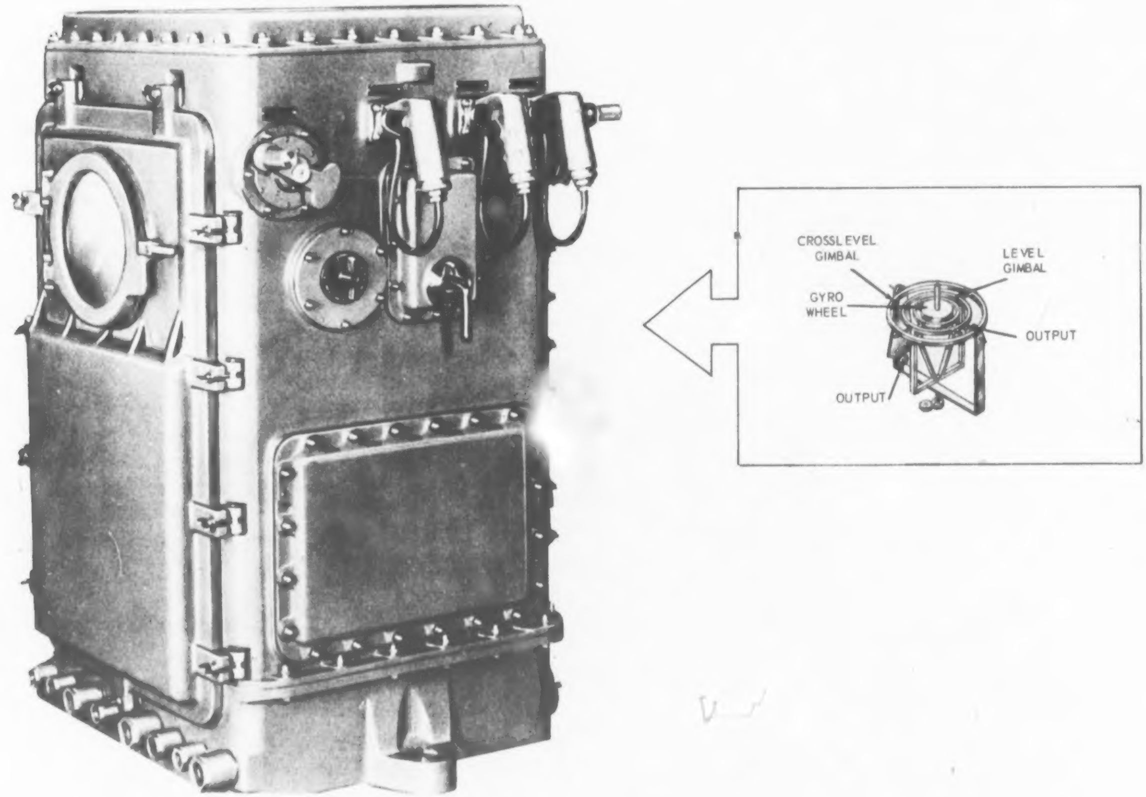
Crosslevel is transmitted to the director as a part of generated elevation from the computer. Level is sent straight from the stable element. Both act to help keep the director lines of sight on target as the ship rolls and pitches.

Radar

You know that radar is a method for determining, by radio echoes, the presence of objects, their range, bearing, and elevation, for recognizing certain of their characteristics, and for making use of this information. Radar began as having rather high-level application, but now there are radars right in gun mounts and turrets. Even though you're not expected to maintain radar equipments, you may have to work with them in spotting, and you should know what their general application is.


1. DIFFERENTIAL
2. CAM
3. COMPONENT SOLVER
4. INTEGRATOR
5. MULTIPLIER

53.105
Figure 7-3.—Computer.



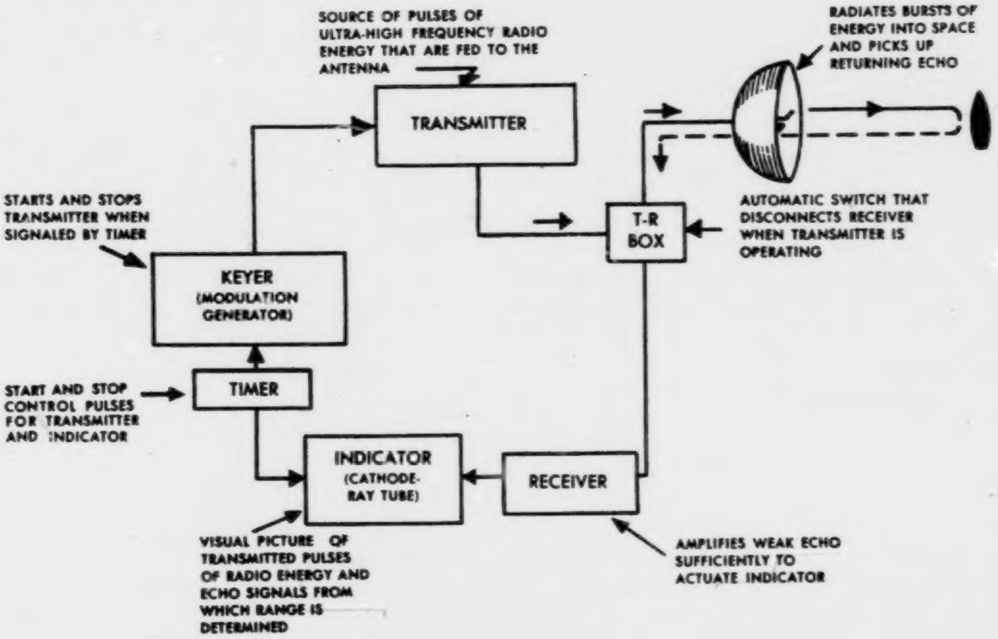
51.103
Figure 7-4.—Stable element.

Here are the bare elements of radar set operation (fig. 7-5). A high-powered TRANSMITTER sends out a short pulse of intense high-frequency radiation from a special ANTENNA so that it issues more or less as a beam. Then the antenna is switched to a sensitive RECEIVER, which picks up radio echoes reflected by targets in the path of the beam. The echo (PIP or BLIP) shows up as a bright spot or a kinked line on the screen of a CATHODE RAY TUBE. (The tube is like that of a television receiver, but you DON'T get a picture—only blips or pips.)

All this happens pretty fast. In one type of radar presentation (type "A"), a beam of electrons sweeps across the tube face at uniform speed in a straight horizontal line, then shuts off. Then a new beam begins crossing the screen again. This (in some radars) happens 10,000 times per second. Each traversal takes 100 millionths of a second (or 100 microseconds). Each time the sweep begins, a TIMER and KEYER cause the radar transmitter to send out its pulse, which moves out at the speed of light (186,000 miles per second or 328 yards per microsecond); then the antenna is switched to receiving until the next pulse.

Now, suppose there is a target at 1640 yards. Traveling at 328 yards per microsecond, the radar pulse hits it in 5 microseconds, and the energy reflected by the target travels the 1640 yards back to the ship in another 5 microseconds. The radar antenna (now connected to the radar receiver) picks it up, and the receiver converts it to an impulse to the cathode ray tube screen.

During this 10-microsecond interval, the electron beam has moved part of the way across


SOURCE OF PULSES OF ULTRA-HIGH FREQUENCY RADIO ENERGY THAT ARE FED TO THE ANTENNA
TRANSMITTER
RADIATES BURSTS OF ENERGY INTO SPACE AND PICKS UP RETURNING ECHO
STARTS AND STOPS TRANSMITTER WHEN SIGNALED BY TIMER
T-R BOX
AUTOMATIC SWITCH THAT DISCONNECTS RECEIVER WHEN TRANSMITTER IS OPERATING
KEYER (MODULATION GENERATOR)
START AND STOP CONTROL PULSES FOR TRANSMITTER AND INDICATOR
TIMER
INDICATOR (CATHODE-RAY TUBE)
RECEIVER
VISUAL PICTURE OF TRANSMITTED PULSES OF RADIO ENERGY AND ECHO SIGNALS FROM WHICH RANGE IS DETERMINED
AMPLIFIES WEAK ECHO SUFFICIENTLY TO ACTUATE INDICATOR

53.106

Figure 7-5. — Elements of a radar system (block diagram).

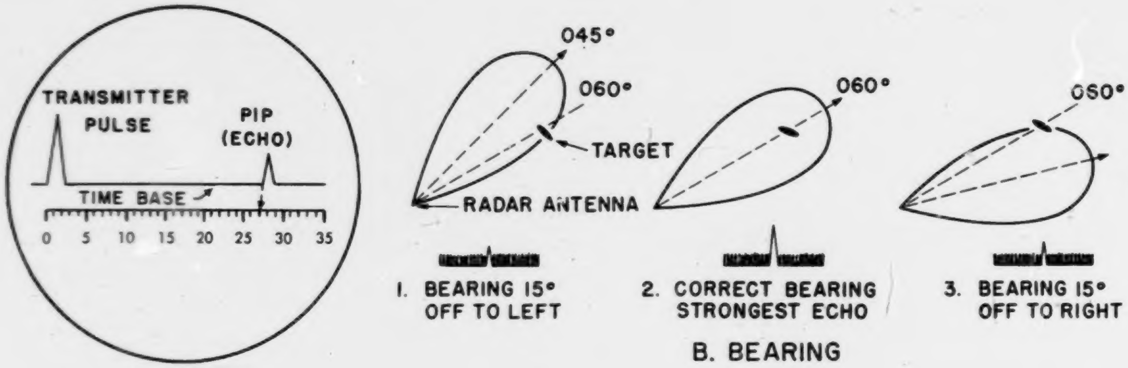
the tube face. The reflected echo jogs it up for an instant as it continues to move its appointed way across the tube. That's the pip.

Because of the electron beam's uniform speed across the tube, the position of the pip is exactly proportional to the range of the target, and the tube face can be calibrated for range as shown in figure 7-6A.

This presentation can also be used to determine bearing. The radar pulse's strength can be plotted in a lobe-shaped pattern, so that as the antenna is trained across the target, the echoes vary in strength as shown in figure 7-6B. Result: the antenna will show the target's bearing when trained to give maximum height of pip.

The type "A" presentation of radar data is only one of several. Another common one is the PLAN POSITION INDICATOR, or PPI-scope. In radars equipped for PPI, the radar antenna is mounted above the ship's structure so that as it revolves continuously in one direction its beam scans the entire surrounding area. The cathode ray tube face shows a "radar map" of the area being covered, with the antenna at the center of the map, and the path of the radar pulses shown as a glowing line revolving about the center as the antenna revolves. Figure 7-7A shows, on the left, a photograph of an actual PPI presentation; on the right is diagrammed the way in which range and bearing can be read from the presentation. Targets and other features of the PPI presentation show in glowing light against the background. The inside of the tube face is coated with fluorescent material so that the spots (representing targets and other features) made to glow by the electron beam will not disappear instantly as the beam's bright line revolves slowly about the tube; instead, they continue to glow for some time.

Especially important in fire control radar are the B-scope and the T&E-scope (figs 7-7B and 7-7C, respectively). The B-scope provides a rectangular presentation of a small segment of the area, with range indicated vertically and bearing horizontally. The T&E-scope presents a view of a plane perpendicular to the antenna axis, with bearing indicated horizontally and elevation vertically. This may sound complicated, but if you look again at figure 7-7C you'll see that this amounts to a "radar-eye" view of what you would see through a gunsight telescope.


TRANSMITTER
PULSE
PIP
(ECHO)
TIME BASE
0
5
10
15
20
25
30
35
045°
060°
TARGET
RADAR ANTENNA
060°
060°
1. BEARING 15° OFF TO LEFT
2. CORRECT BEARING STRONGEST ECHO
3. BEARING 15° OFF TO RIGHT

A. RANGE

B. BEARING

53.107:.108

Figure 7-6.—Type "A" radar presentation.

As you know, there are two main kinds of radar equipment aboard ship—SEARCH RADAR and FIRE CONTROL RADAR. Most search radar is characterized by extreme range, and only fair precision; it's used to detect and designate targets by approximate location. It is also used in navigation, and one type is used to control the movements of friendly aircraft. Fire control radars sets, on the other hand, must be able to determine the range, bearing, and elevation of a target with great precision for effective gunfire. They must also have good target resolution; that is, they must be able to distinguish between pips which are very close together, to permit accurate pointing and training, and spotting of splashes.

Surface fire control radar is used with single-purpose main batteries, on cruisers, to measure only range and bearing to solve the fire control problem. Bearing is determined by use of the lobe-scanning principle and a B-scope presentation. The beam is moved horizontally by oscillating the antenna rapidly through a small angle. When on target, the antenna points at the target in the middle of its arc and the pip is bisected by the vertical line in the center of scope. Range is measured by positioning the movable horizontal range line until it is tangent to the bottom of the pip.

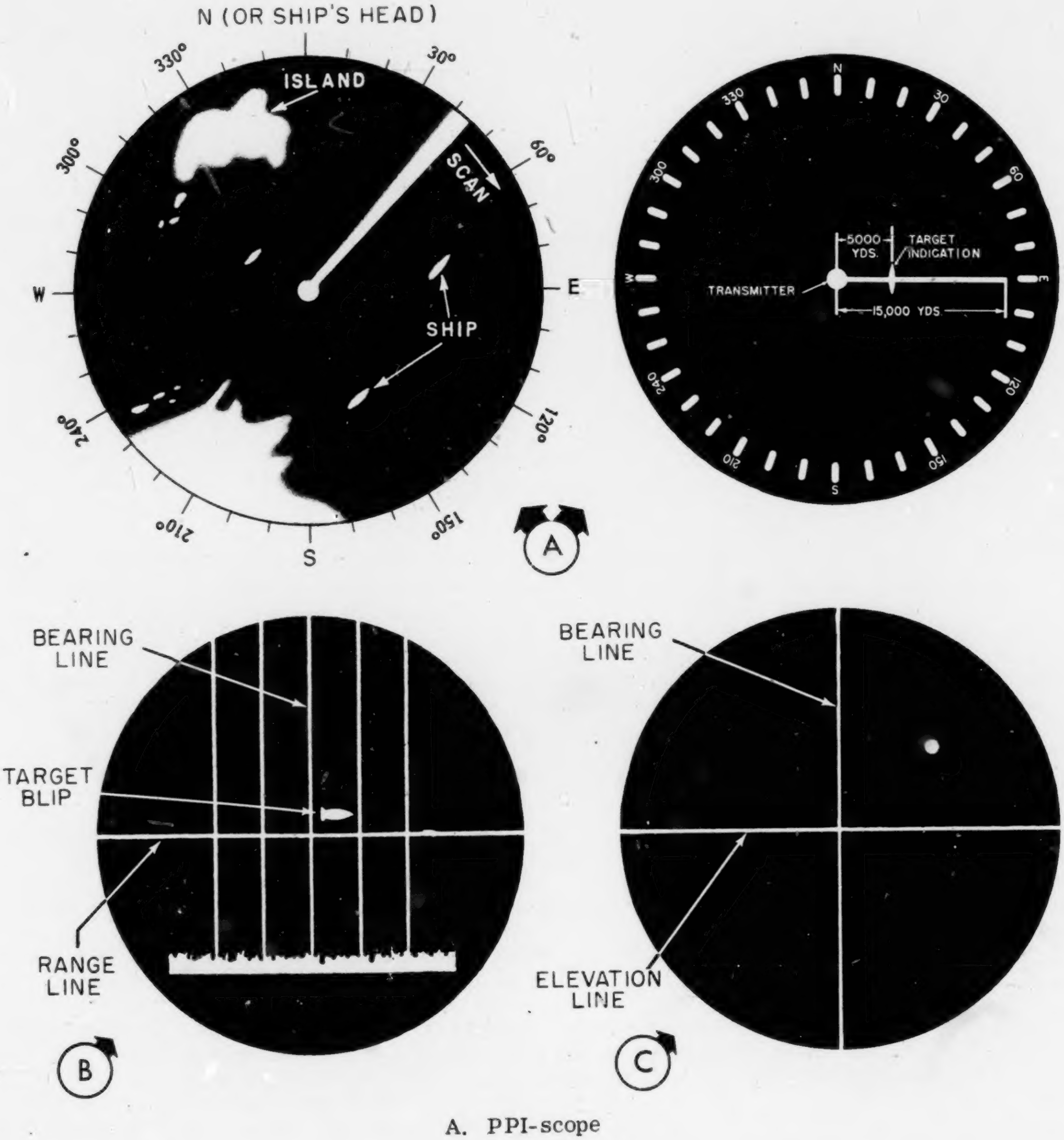
Antiaircraft fire control radar, besides supplying range and bearing, must also furnish target elevation. Range is normally read from an A-scope. For bearing and elevation, the radars employ either SCANNING or LOBE-SWITCHING.

Radar reflections, whatever else they may indicate, don't identify the target as friendly or enemy. But friendly targets can be equipped with a special transmitter which functions when triggered by radar signals. This IFF (Identification Friend or Foe) unit sends out a coded signal for identification.

Though radar can "see" through fog and heavy weather, it can, like all other radio equipment, be JAMMED, either by hostile transmissions that interfere with the echoes, or by "false targets" set up by the enemy in the form of WINDOW—strips of metal foil, or paper strips with a metal coating. You know that some of your gun projectiles and rockets are loaded with window; it can also be dropped from aircraft.

GUN FIRE CONTROL SYSTEMS

As you noted earlier, the complexity of the fire control problem, and hence of the fire control system necessary for its successful solution, increases with the maximum range of the guns associated with the system, since ballistic factors are relatively more important when the time of flight is longer. At the same time, at shorter ranges the position and motion of the target with respect to own ship become relatively more important than the ballistic factors. Moreover, at shorter ranges the time available for solution of the problem is much more limited than at longer ranges. Consequently, instead of a single "universal" fire control system or type of system used in all applications,


N (OR SHIP'S HEAD)
330°
30°
ISLAND
300°
60°
SCAN
W
E
SHIP
240°
120°
210°
150°
S
N
330
30
300
60
5000 YDS.
TARGET INDICATION
W
TRANSMITTER
E
15,000 YDS
240
120
210
150
S
A
BEARING LINE
TARGET BLIP
RANGE LINE
B
BEARING LINE
ELEVATION LINE
C

A. PPI-scope
B. B-scope
C. T&E-scope

53.109
Figure 7-7. — Other types of radar presentation.

you find that there are two main types, each best adapted to a particular kind of application. One of these is the relative-rate type, which efficiently deals with fast targets at short ranges. The other is the linear-rate type, which is particularly well adapted to deal with the more complex ballistic computations required for distant targets.

Examples of both types will be described in more detail later in this chapter but, in order that you may understand better the description that follows of how the fire control system solves the fire control problem, consider briefly the elements of each type.

Linear-Rate Systems

Linear-rate systems are used for both surface and air targets at much longer ranges than those for which relative-rate systems are generally used. The system consists of a director located high in the ship's structure, a computer and stable element closely linked to each other and located in a plotting room in the hull, a radar console located either in the plotting room or the director, and gun mounts (commonly the 5-inch battery, though the system can be connected to control other mounts also). All these elements are interconnected by electrical data transmission circuits, except that the stable element may be mechanically or electrically connected to the computer.

The director is equipped with telescopes, an optical rangefinder, radar equipment (in some installations), data transmitters and receivers, and power drives, so that it can:

a. Determine target bearing, elevation, and range either optically or by radar.

b. Be power driven by computer-generated signals enabling the director crew to verify that the computer is developing the proper fire control solution.

c. "Lock on" the target for automatic radar tracking (i.e., automatically follow the target as its location changes with respect to own ship).

The computer (depending on the specific system) may be either an electromechanical or an electronic-electromechanical unit. It accepts all ballistic factors (including I.V.) as well as target data and data on own-ship course and speed. It transmits gun position data to the gun mounts it controls. And it can send its fire control solution to the director as electrical signals that position the director optical and radar elements to indicate how accurately it is solving the fire control problem. The computer contains no gyroscopic elements.

The stable element contains a gyroscope which, because it remains fixed in attitude, generates a stabilized reference plane to which all angular values received and computed can be related.

The data transmission receivers in the gun mounts control the gun power drives so that the guns will be positioned in accordance with the signals transmitted from the computer. There are several marks and mods of linear-rate systems, including two dual purpose types—the Mk 37 and the Mk 68. The main difference between these two is that the Mk 37 uses the Mk 1A electromechanical analog computer, whereas the Mk 68 system uses an electronic analog computer, and it is capable of tracking targets traveling at supersonic speeds.

Relative-Rate Systems

The essential parts of a simple relative-rate fire control system are a director and a transmission system through which the gun position data required for accurate firing are transmitted to the gun mount. In simpler systems, there may be one director for one or two mounts, and the directors are located fairly close to the mounts they control. Range is either estimated optically and cranked in manually, or measured by radar. The director operator looks through the optical sight on the director (or he may use radar) and tracks the target (that is, as it moves in his field of vision he keeps it aligned with his LOS, as indicated by a reticule in the sight, or in the center of his radar display). This movement affects a gyroscope and a pendulum device in the director case. Electrical pickup devices in the director sense the gyro and pendulum movements and send electrical signals to the gun mounts. The signals correspond to the gun positions required for hitting the target, and they either control the mount power drive so that the guns assume the desired positions, or the gun crews may control gun position manually in accordance with the signals as displayed on dials. Simple relative-rate systems take into account only a few ballistic factors—generally gravity, drift, and air resistance.

In some types of relative-rate systems the director may be divorced from the gyro and pendulum devices. The gyro is then a component in a separate computer. The more complex relative-rate systems will accept additional ballistic data inputs and are more accurate, particularly at longer ranges, than the simpler systems.

The most elaborate systems utilize power-driven directors rather than the manually operated directors of the simple system described above. Under radar control, these can track targets automatically once they are "locked on." The more complex systems also include an additional gyro for stabilization, like the one described earlier for linear-rate systems, and additional computers for wind data inputs and for generation of gun positioning signals for two gun batteries simultaneously.

On-mount fire control elements include data transmission receivers, the power drives, and the sights. (In some systems radar elements may also be installed on the mount.)

A number of fire control systems that work on the relative-rate principle are in use in the Navy at the present time. Most of them are generally associated with 3-inch and smaller guns although some are set up to control larger weapons also. One such system, the GFCS Mk 56, will be explained later in this chapter.

LINEAR RATE FIRE CONTROL SYSTEM MK 37

The Gun Fire Control System (GFCS) Mk 37 is installed in most destroyers, cruisers, carriers, and large auxiliaries. It is the primary means of controlling 5"/38 mounts for both surface and antiaircraft fire. It may be used, with appropriate cross connections, to control machinegun mounts, or major-caliber surface guns in special applications.

SYSTEM FUNCTIONS AND COMPONENTS

The primary functions of the Mk 37 GFCS are to provide:

1. Continuous automatic gun positioning
2. Continuous automatic fuze setting
3. Continuous sight-angle and sight-deflection indication at the guns
4. Continuous-aim, selected-level, and selected-crosslevel fire
5. Star shell fire control

A complete system consists of three major units: a Mk 37 director with a radar; a Mk 6 stable element; and a Mk 1A computer, with the associated instruments at the gun. Destroyers and auxiliaries having Mk 37 systems carry one complete system (fig. 7-8). Cruisers and carriers have two systems.

Directors are installed high in the ship's structure, and stable elements and computers are installed below decks in protected plotting rooms. All elements are connected by a synchro transmission system through one or more switchboards located in plotting rooms.

Normally, each director in a multiple installation controls a designated group of guns and is connected to a designated computer. However, switching arrangements permit any director to control any or all guns and connect to any computer.

INFORMATION FLOW

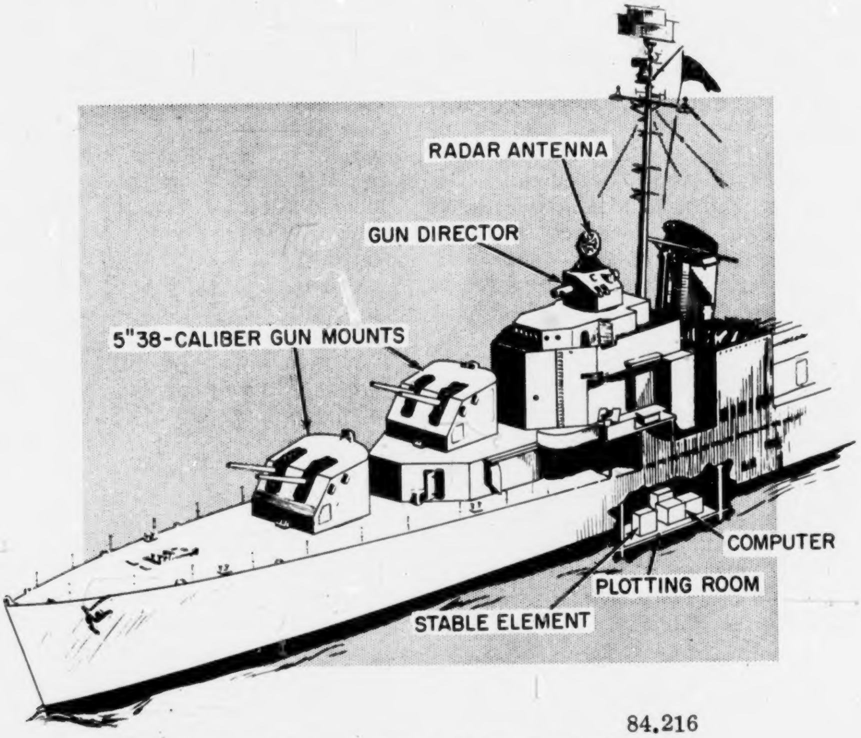
Figure 7-9 is a simplified schematic showing the principal interconnections of a single Gun Fire Control System Mk 37. All electrical circuits between units of the system pass through the fire control switchboard.

The director carries sight telescopes and a rangefinder and radar equipment to measure and transmit to the computer director elevation, director train, and present range. The control officer in the director may estimate target angle, target horizontal speed, and rate of climb, and send these values by telephone to the computer operators. Hand-operated transmitters in the director provide electrical transmission of elevation, deflection, and range spots (i.e., observed corrections) to the computer.

The stable element receives director train from the computer and measures level angle and crosslevel angle. These values are sent mechanically to the computer. A third value, level plus crosslevel divided by thirty, is transmitted from the stable element to the computer to make up a LOS stabilization signal to be transmitted to the director. Other electrical inputs to the computer include own ship course from the gyro compass and own ship speed from the ship speed sensor. Lastly, computer personnel add manual inputs as required.

The computer transmits electrically to the gun mount:

1. Gun elevation order
2. Gun train order
3. Sight angle



84.216

Figure 7-8.—Mk 37 system, destroyer installation.

4. Sight deflection
5. Fuze-setting order
6. Train parallax for a 100-yard horizontal base

These values are used for gun positioning, sight setting, and fuze setting.

In addition, the computer generates and transmits to the director changes in range, elevation, and train. With level and crosslevel, these changes are used to hold the director optics and radar on the target continuously. This process includes keeping the rangefinder and radar on the target.

The Mk 37 Director

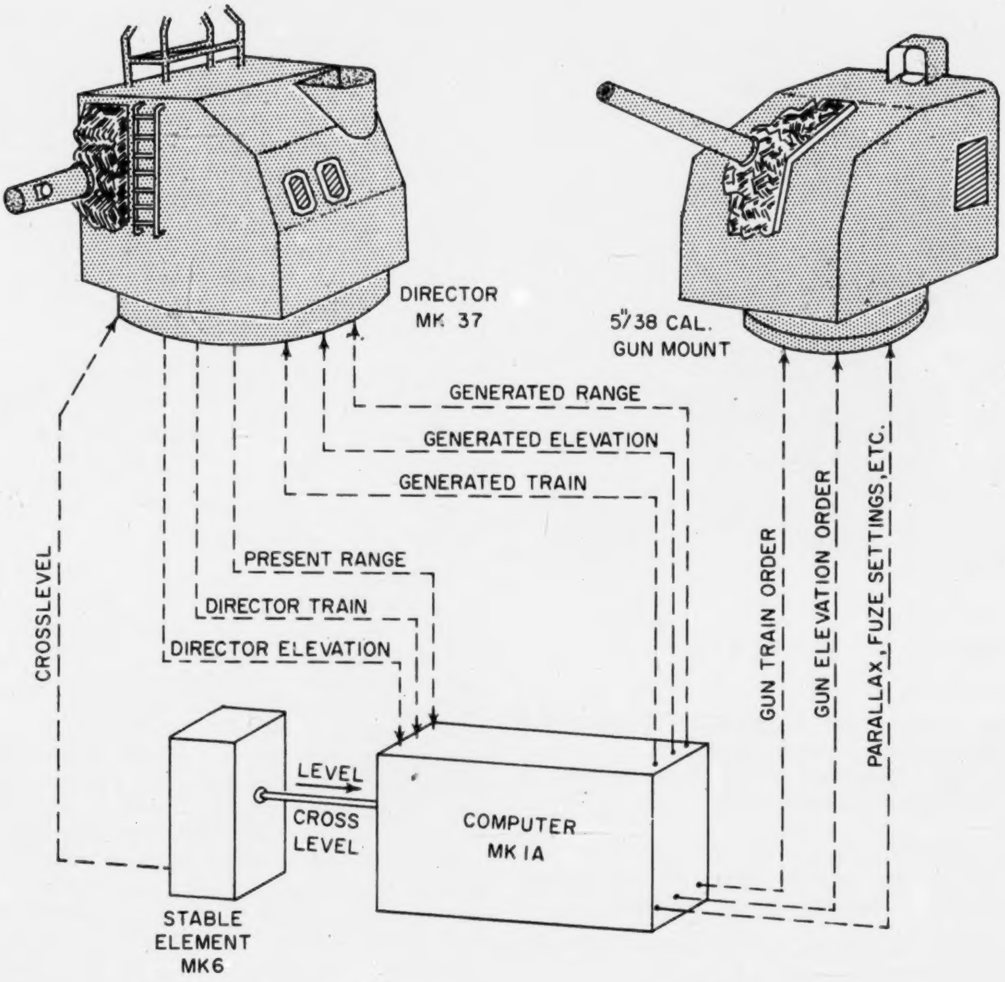
The Mk 37 director is designed, primarily, to control 5"/38 dual purpose guns. Its primary function is to determine target position in terms of:

1. DIRECTOR TRAIN—the angle between the fore-and-aft axis and the vertical plane containing the line of sight, measured in the deck plane clockwise from the bow of the ship

2. DIRECTOR ELEVATION—the elevation of the director's line of sight above the reference plane, measured in the vertical plane containing the line of sight

3. PRESENT RANGE—the distance of the target from own ship, measured in the line of sight

Briefly stated, the director's secondary function is to be the control station for the entire fire control system. Normally, all units operate by remote control from the director, and as long as the problem is being solved correctly, only the gun-loading crews have work to do. The remainder of the crew simply observe operations to ensure that everything is operating correctly. When changes in the problem setup are necessary, the director crew can accomplish them by remote


DIRECTOR
MK 37
5"/38 CAL.
GUN MOUNT
GENERATED RANGE
GENERATED ELEVATION
GENERATED TRAIN
PRESENT RANGE
DIRECTOR TRAIN
DIRECTOR ELEVATION
CROSSLEVEL
GUN TRAIN ORDER
GUN ELEVATION ORDER
PARALLAX, FUZE SETTINGS, ETC.
LEVEL
CROSS
LEVEL
COMPUTER
MK IA
STABLE
ELEMENT
MK6

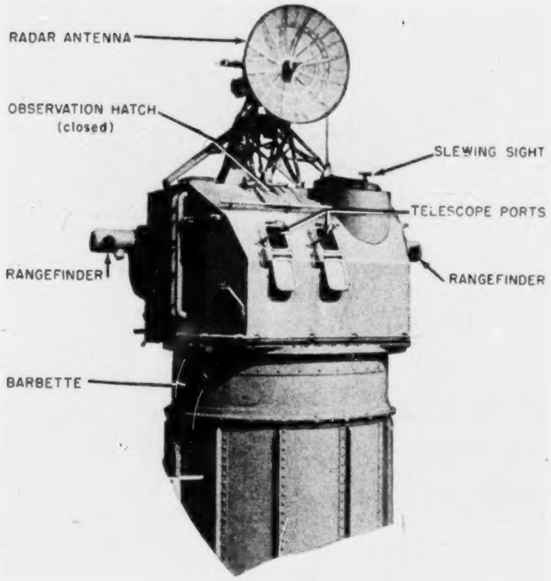
53.114
Figure 7-9. — Flow of information, Mk 37 GFCS.

control. To control the entire system, the director is equipped to

a. Spot service projectile fire
b. Spot illuminating projectile (star-shell) fire
c. Correct computer calculations

CONSTRUCTION. — The director (fig. 7-10) is an armored steel box that can be trained (much like a gun mount) on a precision-aligned roller path mounted on an armored cylindrical barbette built into the ship's structure. It contains an optical rangefinder and pointer's and trainer's prismatic telescopes, radar equipment, power drives for positioning the director, an observation hatch used by a control officer (who may also serve as a spotter), and a slewing sight for positioning the director to pick up the target.

GENERAL OPERATION. — The line of sight is kept on the target in train by turning the entire director on its roller path. The angle the director turns from the centerline of the ship is director train. Rotating the telescope prisms,



3.124
Figure 7-10.—Gun director Mk 37.

the radar antenna and rangefinder elevates the line of sight to give director elevation.

Train and elevation of the director line of sight can be done in four modes:

1. AUTOMATIC (or remote) control of the power drives by signals from the computer, modified as necessary by the handwheels.

2. LOCAL operation of the power drive by means of the handwheels.

3. MANUAL operation by direct gearing from the handwheels.

4. SLEWING or training and elevating rapidly to change targets.

The rangefinder determines range optically. The rangefinder operator can adjust the apparent position of the "wander marks" with relation to the target in the rangefinder field of view. This adjustment is transmitted by a synchro to the computer as a range signal. The computer generates change-of-range signals that are fed back to and control rangefinder adjustment.

Radar is used for target acquisition and tracking, as explained later. It also provides for automatic tracking.

STABILIZATION.—Director optics and the radar antenna are stabilized both in level and crosslevel. Stabilization in level is discussed below. Crosslevel stabilization is done by a servo controlled by a crosslevel synchro signal received directly from the stable element.

The crosslevel servo motor is connected to the telescopes, rangefinder, slewing sight, and radar antenna. The crosslevel drive rotates the telescopes, the whole rangefinder, and the radar antenna about the line of sight by the amount of the crosslevel angle. Thus the telescope crosshairs, the rangefinder, and the radar antenna are kept horizontal, so that director elevation is measured in the vertical plane.

TRAIN, ELEVATION, AND SLEWING CONTROL.—This discussion is chiefly concerned with automatic optical control of the director. Automatic operation in regard to data transmission is similar for radar and optical track; radar will be discussed later. We begin with optical track operation.

Initially, the target is acquired by slewing the director to the target by use of the slewing sight. The slewing sight can drive the director to the target at a maximum rate of speed, much faster than speeds generated by the pointer and trainer handwheels. The slewsight also has a much wider field of vision than is available through the pointer and trainer optics. When the slewsight is on target, the pointer, trainer, and rangefinder operator should see the target in their optics. They then take over and provide more accurate tracking of the target. During the tracking process, director train, director elevation, and range (and any changes thereto) are automatically fed into the Mk 1A computer. Computer solution time can be shortened if the director officer telephones estimated values of target angle, target speed, and target rate of dive to the plotting room. As a matter of fact, the computer can solve the fire control problem without these estimates, and that is most often the case. When the computer starts generating a solution, it transmits computed (generated) corrections to the director, keeping it on target as long as the solution remains correct.

Computed bearing correction consists of increments of computed change in director train, including changes in train caused by relative target motion, changes in own ship's course, and the effect of deck tilt. If computed bearing correction is correct, the line of sight stays on target without handwheel motion.

If the director while in automatic tends to drift off target, the trainer can, by closing the rate control key and keeping the line of sight on target with his handwheels, introduce a correction into the computer. This is necessary if there is a change in target course or speed. If the target becomes obscured, the trainer allows computed bearing correction to continue to drive the director until the target reappears. Rate controlling also can be accomplished by the computer operator.

The description of train control applies generally in elevation control. The telescope prisms rotate; the rangefinder rotates about its longitudinal axis; and the radar antenna rotates about its mounting to follow the target in elevation. Now director elevation is the sum of target elevation and level angle. To hold the LOS on target, in elevation, director elevation must be changed by adding increments of generated elevation and continuous corrections in the value of level. These are received from the computer and are fed to the sights, rangefinder, and radar, so that the LOS is stabilized in level as it tracks the target.

To shift from one target to another or to make any other large change in elevation and train, the director officer may slew the director. He does this by operating a key on the slewing sight and pointing the sight at the target. This takes away control of the director from the pointer and trainer, and drives the director at high speed until its line of sight coincides with that of the slewing sight. Slewing brings the target into the fields of the optics, and thus designates the target to the director crew.

RANGE CONTROL AND SPOT TRANSMISSION. — The rangefinder's optical elements and range synchro transmitter are adjusted for range by a differential, which accepts inputs both from the operator's knob and from a servo controlled by a generated range signal from the computer. Thus the rangefinder operator can correct the rangefinder adjustment and transmit an accurate value of observed present range. He also can rate control the system by pressing a button and operating his range knob, as explained in connection with train operation.

The rangefinder operator has a transmitter for sending spots in range to the computer. The director control officer has a transmitter for sending bearing and elevation spots to the computer.

RADAR. — The automatic-tracking fire control radar has its antenna and parabolic reflector mounted atop the director, with indicator scopes and other components in the director and below decks. This radar has three types of antenna scan: spiral for target acquisition, conical for tracking, and circle for spotting shell splashes in surface fire.

Normally, the automatic tracking feature makes rate control corrections unnecessary. Tracking signals — representing target range, bearing, and elevation — are generated from radar information and compared with generated range, bearing, and elevation. Differences between computed and radar values are transmitted to the director as corrections, to reposition it in accordance with the radar information, and to the computer to correct its solution until it matches the radar values. Once the target has been acquired by radar, this process is continuous and automatic.

The Computer Mk 1A

The computer Mk 1A is the mechanical brain of the GFCS Mk 37. It computes continuous gun orders, which contain all significant factors that affect fire.

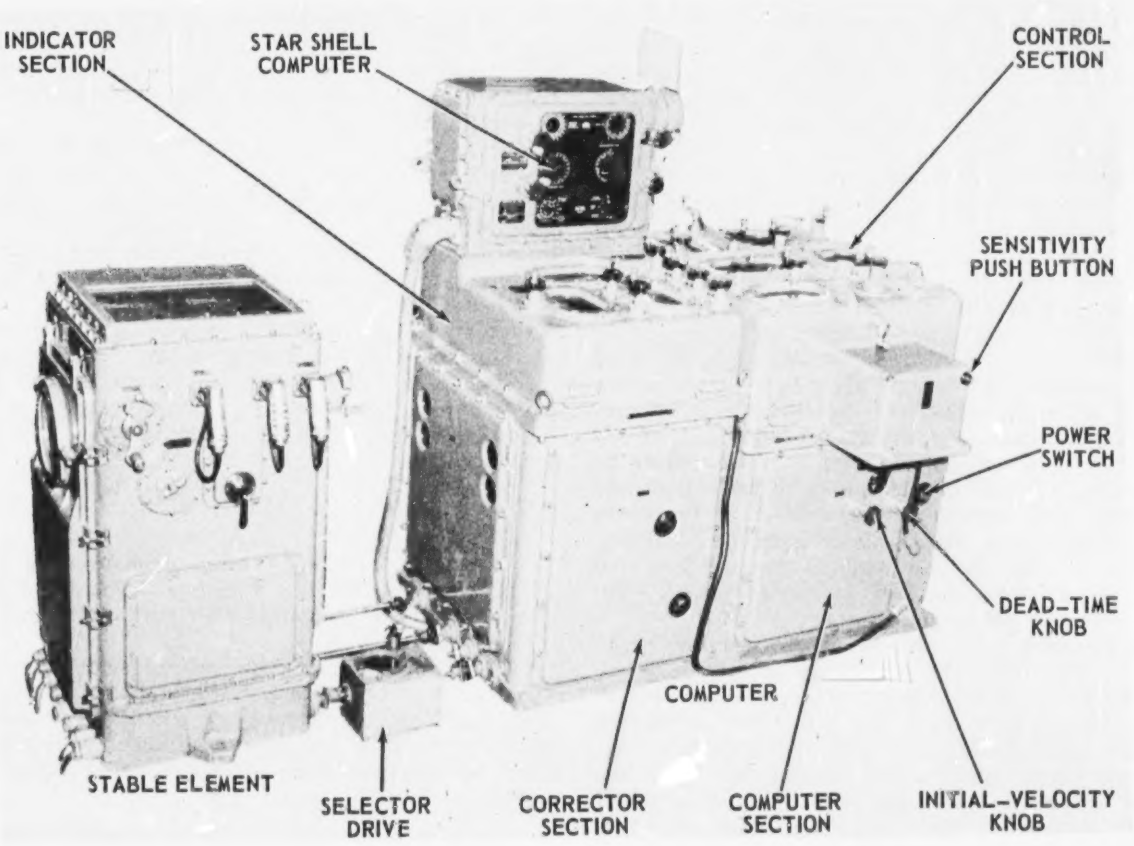
The gun orders, fuze-setting order, and parallax corrections are continuously transmitted from the computer to the gun mounts, where they are used to point the guns continuously, and to time fuzes so that the projectiles will explode at the predicted target position.

The computer is build in four sections: control section, indicator section, computer section, and correction section. The first two are mounted on top of the second two, as shown in figure 7-11. The star shell computer, an independent unit, is mounted atop the main computer.

The control section contains the mechanisms for computing and controlling rates. This section has most of the knobs, cranks, and dials. The computer section contains the mechanisms used to calculate ballistics. The indicator section displays, on dials and counters, the results of ballistic calculations — sight angle, sight deflection, fuze order, and advance range. The correction unit computes an indicated gun train order, gun elevation order, and parallax.

The computer's functions are:

1. To control continuously the positioning of dual purpose guns and the setting of fuzes and sights for either AA or surface fire
2. To aid the director crew in keeping the line of sight on target


INDICATOR SECTION
STAR SHELL COMPUTER
CONTROL SECTION
SENSITIVITY PUSH BUTTON
POWER SWITCH
DEAD-TIME KNOB
COMPUTER
STABLE ELEMENT
SELECTOR DRIVE
CORRECTOR SECTION
COMPUTER SECTION
INITIAL-VELOCITY KNOB

51.103;53.105
Figure 7-11.—Mk 1A computer and Mk 6 stable element.

3. With the star shell computer, to permit part of the dual purpose battery to be set continuously for illumination of a surface target while firing other mounts at the target in the usual manner

STAR SHELL COMPUTER.—The star shell computer is an independent accessory with which it is possible to direct the fire of one mount for illuminating a target or target area while the rest of the battery, under the control of the main computer, fires for effect. The mount controlled by the star shell computer uses illuminating projectiles (colloquially called STAR SHELLS) that are aimed and time-fuzed to burst above the target.

OUTPUTS AND INPUTS.—The computer reckons relative target motion rates, which are used in generating changes in target range, bearing, and elevation. Changes in own ship's course are taken into account in computing changes in target bearing. Because rangefinder ranges are often somewhat erratic, the computer uses generated range for its calculations to improve smoothness of operation. Measured relative target bearings and target elevation are used because they can be measured accurately and smoothly. Target elevation is obtained by subtracting level from director elevation. Relative target bearing is obtained by adding deck-tilt correction to director train.

The computer generates increments of range, relative bearing, and elevation. Increments of relative bearing are sent to the director train receiver-regulator to position the line of sight according to the generated value of director train. It takes into account both deck-tilt correction and changes of own ship's course. Thus, if the solution is correct, bearing correction will keep the line of sight on the target in train while the ship rolls, pitches, and changes course.

Increments of elevation are added — in the computer — to the level plus crosslevel function quantity. The sum, called elevation correction, controls the director elevation power drive to hold the LOS on target in elevation if the computer solution is correct.

The changes in director train and elevation from bearing and elevation corrections show up in the new values of director train and elevation. Thus there is a continuous feedback into the computer since the director continuously transmits director train and elevation to the computer. The computer and director together form a regenerative system. This allows the director to follow an obscured target by riding the computer solution; as long as the solution is correct, the director will remain on target.

Wind computations are made empirically. Air-density corrections are computed separately and applied to the computer as a change in initial velocity. Initial velocity settings are otherwise based on equivalent service round (E.S.R) data — explained in GMG 3&2, NP 10185-A.

The quantities considered in the computation of sight angle, sight deflection, and fuze setting are:

Sight angle

1. Elevation prediction
2. Superelevation
3. Wind elevation correction
4. Initial velocity elevation correction
5. Complementary error
6. Elevation parallax correction
7. Elevation spot

Sight deflection

1. Deflection prediction
2. Drift
3. Wind deflection correction
4. Deflection spot

Fuze setting

1. Time of flight
2. Dead time

The Mk 6 Stable Element

The Mk 6 stable element (fig. 7-11) is located in the plotting room next to the Mk 1A computer. In general, its primary function is to measure level angle and crosslevel angle. The stable element does this by using a gyroscope to establish true vertical and true horizontal.

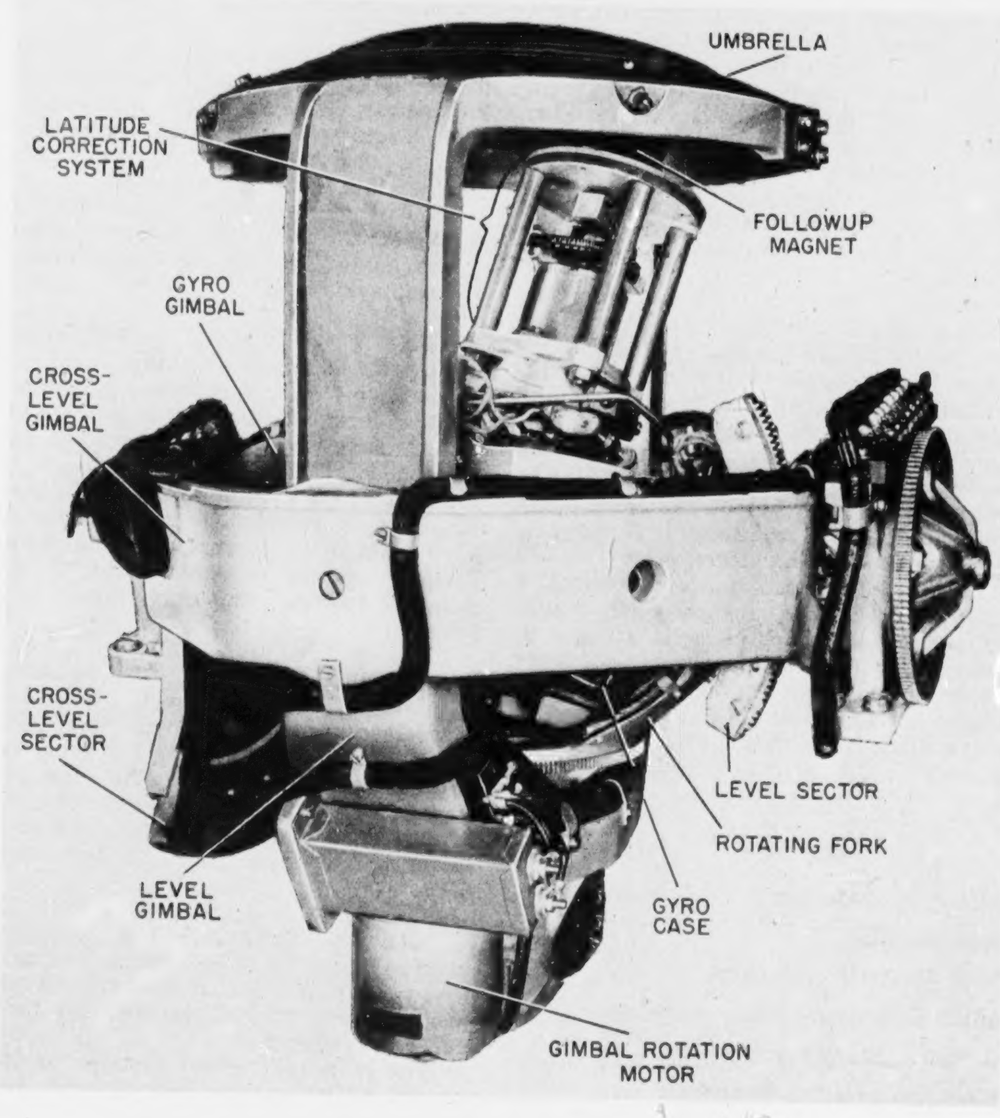
The principal functional elements of the Mk 6 stable element are the sensitive element, the measuring group, the righting system, and the followup system.

SENSITIVE ELEMENT. — The sensitive element is the heart of the stable element; it consists of the gyroscope, gyro case, gyro gimbal, and rotating fork (fig. 7-12). The gyro wheel and the ball-bearing mounted axle form the rotor of a high-speed (8500 rpm) induction motor. The gyro assembly pivots within the gyro gimbal on a case axis perpendicular to the spin axis. The gyro gimbal is supported by the arm of the rotating fork on the gimbal axis. This axis arrangement gives the gyro three degrees of freedom.

MEASURING GROUP. — The measuring group consists of an inner (level) gimbal, an outer (crosslevel) gimbal, training gear, and an umbrella containing two pairs of followup coils, one pair for level and the other for crosslevel (fig. 7-12). With this gimbal arrangement, level is measured in a vertical plane while crosslevel is measured in a plane perpendicular to the deck.

RIGHTING SYSTEM. — The righting system makes the gyro axis assume and maintain a true vertical position. It has two principal parts — the mercury control system and the latitude correction system.

The mercury control system consists of two interconnected tanks — one on each side — containing mercury and a gimbal rotation motor that rotates the entire gyro assembly at 18 rpm. While the gyro wheel is horizontal, the mercury level in both tanks is the same. If the wheel tilts from the horizontal, the tanks also tilt, and mercury flows at a controlled rate from the higher tank to the lower. The net effect of the mercury flow and gimbal rotation is that by the time the mercury has reached the lower tank, the tank has rotated 90° from the low point of the gyro wheel, and the pressure exerted here causes the gyro spin axis to precess back to vertical. Thus the gyro automatically erects


UMBRELLA
LATITUDE CORRECTION SYSTEM
FOLLOWUP MAGNET
GYRO GIMBAL
CROSS-LEVEL GIMBAL
CROSS-LEVEL SECTOR
LEVEL SECTOR
ROTATING FORK
LEVEL GIMBAL
GYRO CASE
GIMBAL ROTATION MOTOR

110.67
Figure 7-12.—Complete stable element gyro assembly.

itself when put into operation, and remains stabilized in a vertical position.

FOLLOWUP SYSTEM.—The followup system performs the actual measurement of level angle and crosslevel angle. The system (fig. 7-12) includes the umbrella and followup coils (mentioned in connection with the measuring group), a followup a-c electromagnet on top of the gyro case, and a level and crosslevel followup (not illustrated). When (because of ship's pitch or roll) the umbrella is not aligned with the gyro, the followup magnet induces unbalalced voltages in the followup coils. The algebraic sum of these voltages goes to an amplifier which uses the amplified signal to control rectifier tubes whose output feeds a d-c servo motor. The motor drives the umbrella until it is aligned with the gyro. Thus the umbrella "follows" the gyro spin axis. The followup units also drive synchro transmitters and operate firing switches for selected level and crosslevel fire.

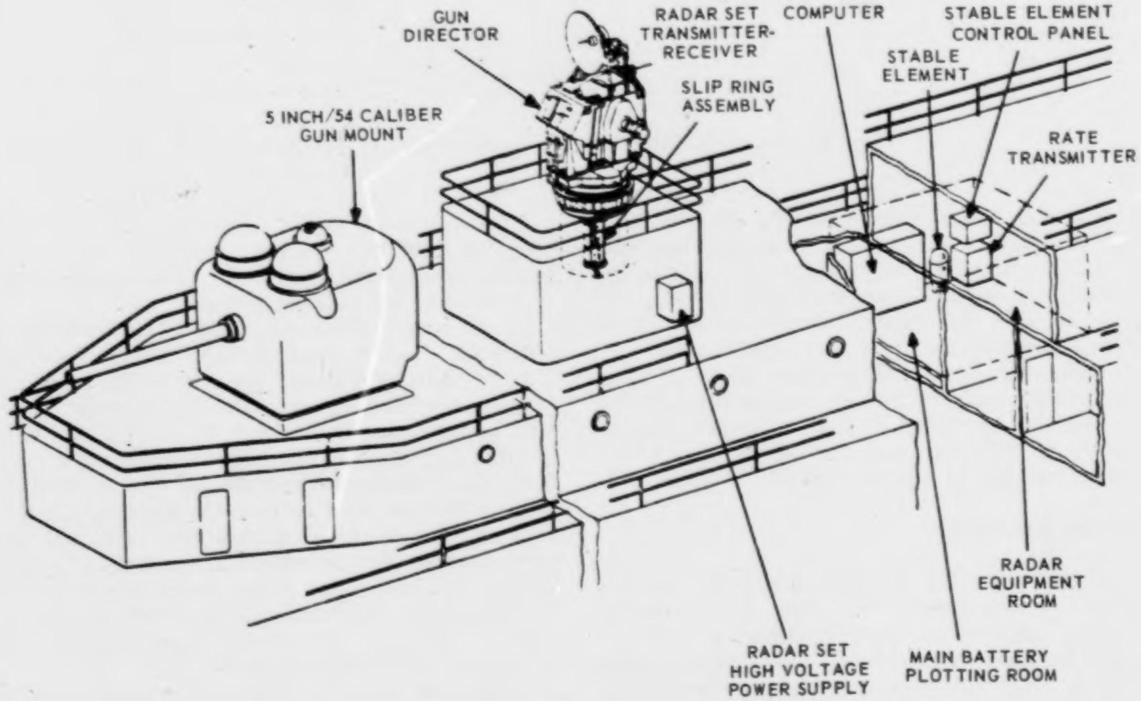
LINEAR-RATE FIRE CONTROL SYSTEM MK 68

The GFCS Mk 68 is a dual-purpose, fully automatic system used to control 5"/54 and 3"/50 guns. Basically, GFCS Mk 68 performs the same functions as GFCS Mk 37, except that it is capable of tracking targets traveling at supersonic speeds. The Mk 68 system has numerous dials, handcranks, indicator lights, and similar operating controls, which give it the appearance of being much more complicated than the Mk 37. Most of these, however, are for checks and test purposes and for placing the system in standby condition. Actually, the system is designed to operate very simply and with fewer personnel than the Mk 37 system. Testing and maintenance have also been simplified through plug-in module design, built-in testers, and test panels. A typical Mk 68 system layout aboard a DLG is shown in figure 7-13.

INFORMATION FLOW AND SYSTEM COMPONENTS

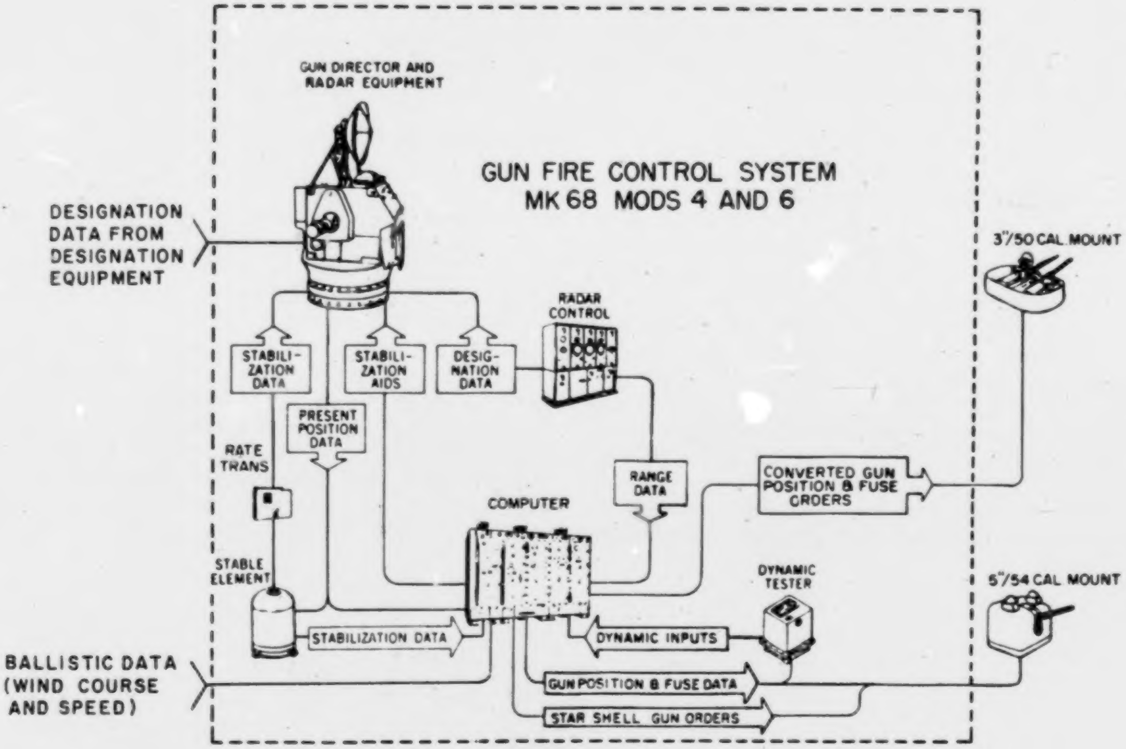
System components and primary data flow are shown in figure 7-14. The components are described separately as to their function in the system. Primary data flow is much the same as in the Mk 37 system.

Before treating each unit separately, a brief, overall look at the system's data flow may be useful. The director, which serves as the battery control station, furnishes present target position to the computer and stable element. The computer Mk 47 uses this information plus own ship's motion data and ballistic data to compute gun orders for the 5" guns. The computer Mk 116


GUN DIRECTOR
RADAR SET TRANSMITTER-RECEIVER
COMPUTER
STABLE ELEMENT CONTROL PANEL
STABLE ELEMENT
SLIP RING ASSEMBLY
5 INCH/54 CALIBER GUN MOUNT
RATE TRANSMITTER
RADAR EQUIPMENT ROOM
RADAR SET HIGH VOLTAGE POWER SUPPLY
MAIN BATTERY PLOTTING ROOM

170.13

Figure 7-13.—Arrangement of GFCS Mk 68.


GUN DIRECTOR AND RADAR EQUIPMENT
GUN FIRE CONTROL SYSTEM MK 68 MODS 4 AND 6
DESIGNATION DATA FROM DESIGNATION EQUIPMENT
3"/50 CAL. MOUNT
RADAR CONTROL
STABILI-ZATION DATA
STABILI-ZATION AIDS
DESIG-NATION DATA
PRESENT POSITION DATA
RATE TRANS
RANGE DATA
CONVERTED GUN POSITION & FUSE ORDERS
COMPUTER
STABLE ELEMENT
DYNAMIC TESTER
5"/54 CAL MOUNT
STABILIZATION DATA
DYNAMIC INPUTS
BALLISTIC DATA (WIND COURSE AND SPEED)
GUN POSITION & FUSE DATA
STAR SHELL GUN ORDERS

166.122
Figure 7-14.—Gun fire control system Mk 68 data flow.

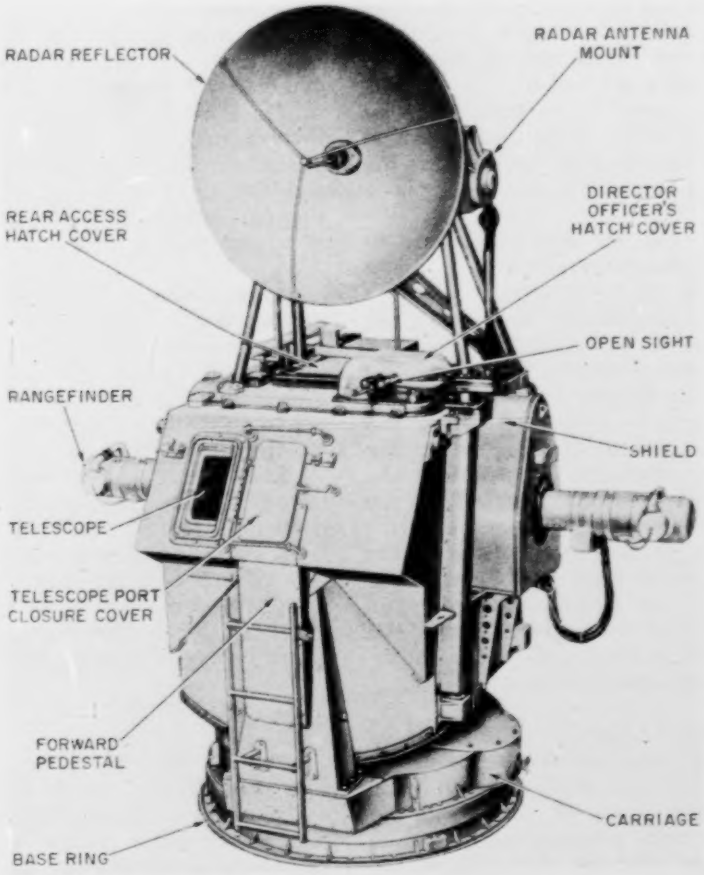
(or the gun order converter Mk 20 and star-shell computer Mk 1) is used in conjunction with the Mk 47 computer to produce gun orders for the 3-inch guns and star-shell gun orders. The stable element, which establishes the stabilized horizontal reference plane, provides the director and computer with stabilization signals. Data flow between major units is routed through the fire control switchboard and is continuous as long as the director remains on target—either in radar control or optical control.

Gun Director Mk 68

Gun director Mk 68 determines the present position of the target by either optical means or radar equipment, part of which is located on the director. The optical equipment consists of the director officer's open sight and binoculars mounted on a movable sight bracket, a tracker's telescope, and a stereoscopic rangefinder; the radar equipment at the director (This will vary with the different system mods.) is the antenna mount and reflector (fig. 7-15). (The radar console is located in the plotting room.)

The normal tracking mode of the director is automatic radar control. The radar provides ranges and angle error signals to the train and elevation power drives. The train power drive rotates the entire director to position the line of sight in train; the elevation power drive rotates the optical equipment and the radar antenna about their elevation axis to position the line of sight. Another power drive (crosslevel power drive) positions the director shield, keeping the elevation axis of the optics and radar antenna aligned with the horizontal reference plane established by the stable element. Thus director elevation is measured in the vertical plane.

Alternate methods of director control include power operation by means of handwheel or one-man control units, and computer control.


RADAR REFLECTOR
RADAR ANTENNA MOUNT
DIRECTOR OFFICER'S HATCH COVER
REAR ACCESS HATCH COVER
OPEN SIGHT
RANGEFINDER
SHIELD
TELESCOPE
TELESCOPE PORT CLOSURE COVER
FORWARD PEDESTAL
CARRIAGE
BASE RING

3.124(170)D

Figure 7-15. — Representative gun director Mk 68, front view.

TRAIN MOVEMENT. — The telescope, open sight, rangefinder, and radar antenna mount are fastened to the shield and move with it in train. The entire director is rotated about an axis perpendicular to the deck plane to move the director line of sight in train. The electrical connections between the stationary ship structure and the rotating director are made through a slipring assembly in such a manner that train movement is unlimited in either direction. This feature eliminates the necessity for train limit stops and electrical limits.

ELEVATION MOVEMENT. — The telescope, open sight, rangefinder, and radar antenna are mounted so that their lines of sight may be elevated with respect to the shield. The elevation axes of these components are all parallel and the lines of sight of each component are perpendicular to the elevation axis. For practical purposes, all of the elevation planes are parallel. The lines of sight and the radar beam are all moved through the same elevation so that they remain parallel.

The director elevation gearing can move the lines of sight and the radar beam from a depression angle of -25 degrees to an elevation angle of 95 degrees. Limit stops and electrical limits in the power drive protect the drive mechanisms from damage that would result if these limits were exceeded.

The telescope is constructed so that the instrument body does not move in elevation. Elevation of the telescope line of sight is effected by rotating an objective mirror mounted on bearings inside the telescope body.

The open sight contains a binocular and peep sight at the end of the sight arm. The line of sight is moved in elevation by rotating the open sight about an axis parallel to the telescope elevation axis.

The rangefinder line of sight is moved in elevation by rotating the entire rangefinder about its longitudinal axis. An independent elevation mechanism in the rangefinder drive permits rangefinder elevation to be offset from director elevation when it is necessary to adjust the reticle pattern with the target.

The radar antenna is supported above the shield by a radar antenna mount. The radar beam is moved in elevation by rotating the entire antenna about an axis parallel to the elevation axes of the optical equipment.

A level angle is geometrically added to the elevation of the lines of sight and radar beam to cancel the effect on elevation of roll and pitch of the ship. The level angle is generated by a stable element below decks and is automatically transmitted to the director.

CROSS-LEVEL MOVEMENT.—The director shield is mounted on trunnions so that the entire shield can be rotated in cross-level to keep the elevation plane's lines of sight and the radar beam in a vertical position regardless of the ship's rolling and pitching. The axis of the crosslevel trunnions is parallel to the deck plane.

The director crosslevel gearing can move the shield through an angle of 34 degrees each side of the zero position. Limit stops and electrical limits in the power drive and buffers on the director pedestals protect the crosslevel drive and shield from damage that would result if these limits of movement were exceeded.

Director Control and Operating Modes

Gun director Mk 68 is operated by a director officer, tracker, and rangefinder operator. The director crew's operating stations are inside the shield, they perform all procedures necessary to place the director in operation. Additionally, the director officer is responsible for selecting the operational mode of the director and controlling and supervising the operation of the GFCS Mk 68 and gun batteries controlled by the system.

The director has two basic types of control—handwheel and normal. The type of control is selected by the director officer at his control panel. Handwheel control is used against stationary and slow moving surface targets. The director officer operates the elevation handwheel, and the tracker operates the train handwheel. Normal control is used against all other types of targets and has the following modes of operation:

1. Auto-track. The radar is locked on target and has control of the power drives.
2. Console mode. The radar has control of the power drives but is not locked on target; the handwheel and the indicator scopes on the radar console are used to establish and position the line of sight.
3. Director officer control mode. The director officer's one-man control unit and optics are used to establish and position the line of sight.
4. Tracker control mode. Tracker's one-man control unit and telescope are used to establish and position the line of sight.
5. Target designation mode. In this mode the power drives slew to the designated position.

Radar AN/SPG 53

The AN/SPG-53 radar is a part of the Mk 68 fire control system. It affords control of the entire system from the radar console. The radar supplies present range to the computer and angle-error signals to the director train and elevation power drives. In the console mode of operation the two radar operators (range operator and range trainer), using handcranks and slew controls, keep the line of sight on target by observing the target echo on indicator scopes. The handwheels and slew controls are also used for modifying target designation signals in the target designation mode.

In the automatic tracking mode (normal mode), the director position is controlled by the angle tracking loop. The target-video signal is applied to the angle error detecting system, which determines the tracking error and generates bearing and elevation error signals. These error signals are sent to an amplifier, which supplies power to the director amplidynes.

Computer Mk 47

Computer Mk 47 is housed in two aluminum sections bolted together to form a single cabinet.

Each section has a front and a rear compartment. The front compartments house the electromechanical assemblies, and the rear compartments house the electronic units and power supplies. All assemblies are plug-in type. All operating controls, switches, and indicating dials are conveniently located on the front of the computer, (fig. 7-16).

The computer utilizes target present position to compute future target position. Gun and fuze-setting orders based on this information are then computed and transmitted to the gun mounts (fig. 7-14).

Automatic control is the normal method of computer operation. The computer has three primary modes of operation determined by the type of target — surface, AA-sonic, and AA-supersonic — and the wind track mode used to track weather balloons for gathering ballistic wind data. For surface targets, the computer can also be operated in local control, manual rate control, or optical range submode. In automatic control the computer receives continuous target position data from the director, stabilization data from the stable element, and own-ship course and speed from the ship's compass and speed sensor. It solves the relative motion problem by automatic rate control, and it supplies the director with the generated quantities and stabilization signals necessary to keep the line of sight on target.

Once the computer has been set up for automatic control, the operator's main function is to monitor it for smooth and correct operation. But during certain types of fire, particularly surface fire, the computer may have to be shifted to local control, manual rate control, or the optical range submode of operation, depending on the tactical problem to be solved. A brief description of each follows.

LOCAL CONTROL. — In local control operation the line of sight DOES NOT originate in the director. The source of data used to establish the LOS in the computer is from outside the gun fire control system. Target position is manually set into the computer by handcranks. Local control is used for indirect fire.

MANUAL RATE CONTROL. — When tracking targets with slow relative rates, it is sometimes advantageous to manually rate control; solution time is reduced, and a smoother solution may be obtained. Because the computer operator has an overall picture of the tactical situation, he is in an ideal position to correct the rate errors without over or under rate controlling. Rate control corrective inputs are introduced by the computer handcranks.

OPTICAL RANGE OPERATION. — In the optical range submode of operation a continuous, correct, observed present range is not available to the computer. The range servo receiver is deenergized so that the computer's present range will not follow the observed present range signals. The computer's range system becomes a regenerative network, where increments of generated range are used to keep present range up-dated in the computer. When a correct observed range is available, the computer operator uses his handcrank to make present range corrections.

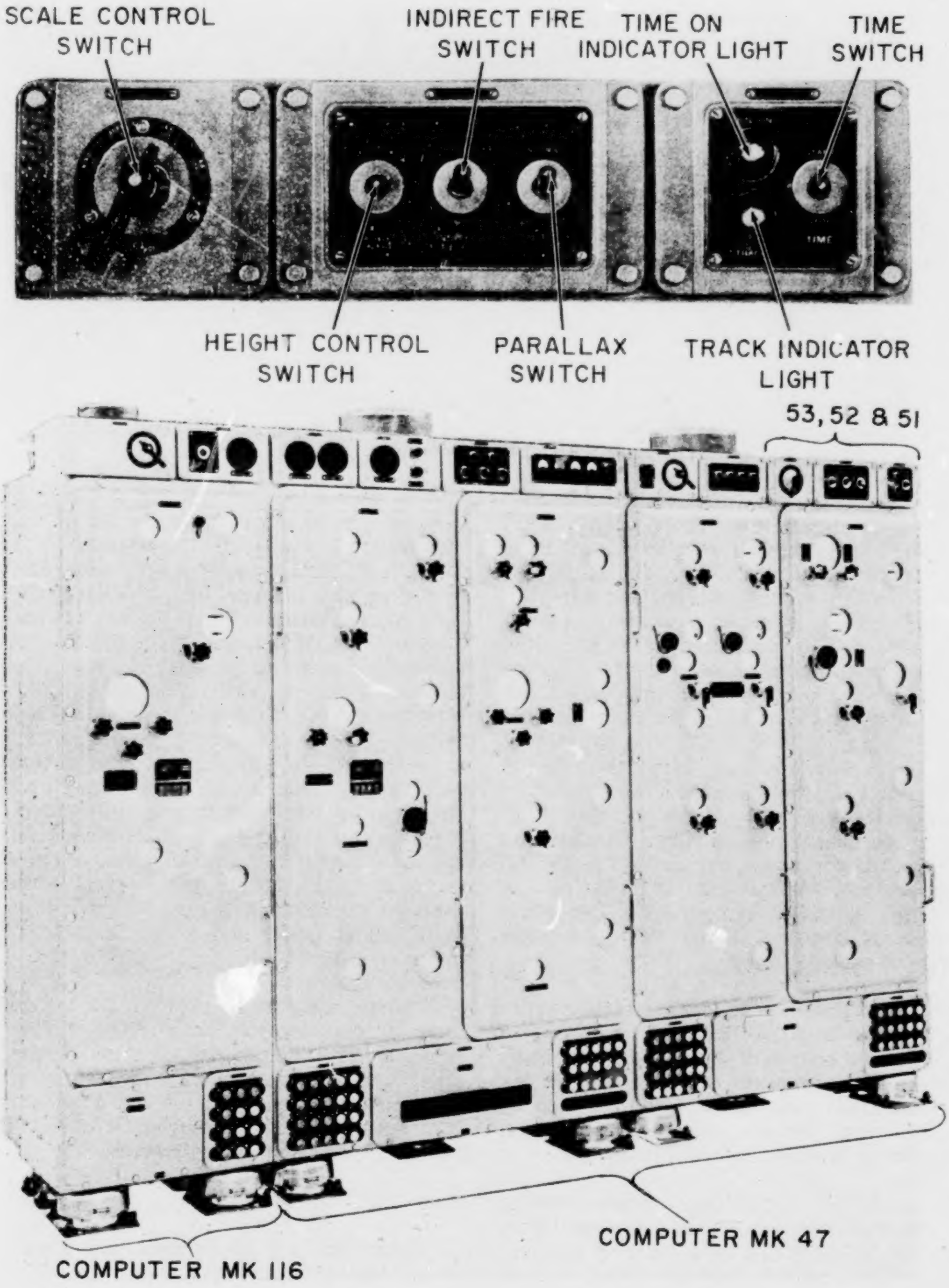
Computer Mk 116

The computer Mk 116 (fig. 7-16) is designed for use with some mods of the Mk 47 computer. The Mk 116 computer discussed here functions in three different modes of operation — NORMAL 3"/50 mode, STAR-SHELL 5"/54 mode, and RAT (rocket-assisted torpedo) mode. In NORMAL 3"/50 mode, it operates in conjunction with the Mk 47 computer to derive gun orders for 3"/50 caliber guns; it transmits these gun orders directly to the 3-inch gun mounts. In STAR-SHELL 5"/54 mode, it operates with the Mk 47 computer in surface mode to derive 5"/54 caliber gun orders and fuze-setting orders for illuminating fire, and it transmits these orders directly to the 5-inch gun mounts. In RAT mode, it supplies relative target bearing, which is used as an aid in the control of anti-submarine rockets (ASROC). Except for a few hand inputs (spots and I.V.), the Mk 116 computer receives all inputs from the Mk 47 computer.

The primary function of the Mk 116 computer is to produce gun orders for the 3"/50 caliber battery. The computer contains a prediction and ballistics section for determining target position at the end of time of flight, and a deck tilt section for converting and transmitting gun orders in the proper coordinates.

Converter Mk 20

Converter Mk 20 is used with some Mk 47 computers that are not supplied with Mk 116 computers. The converter, which is installed in the plotting room adjacent to the Mk 47 computer, is used to change 5"/54 caliber gun orders to


SCALE CONTROL SWITCH
INDIRECT FIRE SWITCH
TIME ON INDICATOR LIGHT
TIME SWITCH
HEIGHT CONTROL SWITCH
PARALLAX SWITCH
TRACK INDICATOR LIGHT
53, 52 & 51
COMPUTER MK 116
COMPUTER MK 47

53.105(170)D
Figure 7-16.—Computer sections.

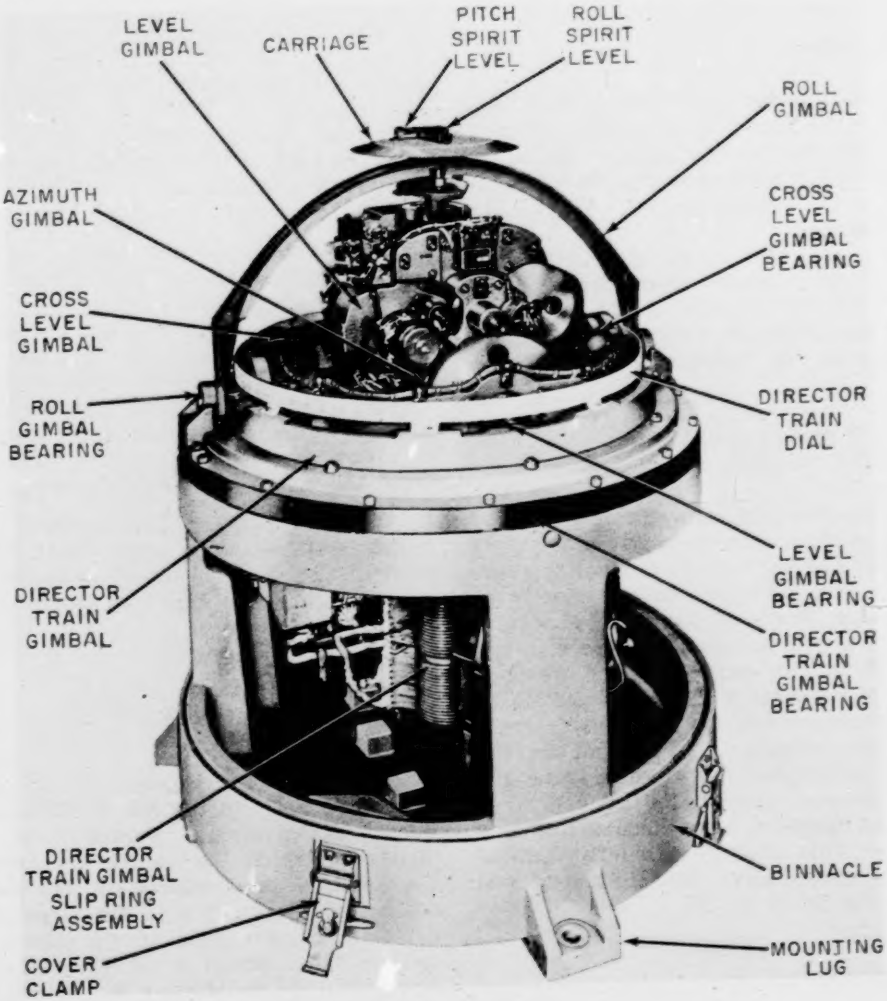
3"/50 caliber gun orders. All power and information (other than spots and I. V.) necessary to perform the conversion computations are received from the Mk 47 computer. Therefore, the converter will operate only when the computer is on and transmitting gun orders. Except for setting in spots and I. V., operation of the converter is automatic.

Star-Shell Computer Mk 1

In some systems not supplied with Mk 116 computers, Star-Shell Computer Mk 1 is used to compute star-shell gun orders and fuze-setting orders for 5"/54 caliber gun mounts. It can be operated in two modes — controlled fire or search. In the controlled fire mode, employed when a specific target is to be illuminated, the Mk 47 computer must be operating. In the search mode, the star-shell computer can be operated independently of the Mk 47 computer.

Stable Element Mk 16

The primary function of the Mk 16 stable element and its associated equipment (fig. 7-17)


LEVEL GIMBAL
CARRIAGE
PITCH SPIRIT LEVEL
ROLL SPIRIT LEVEL
ROLL GIMBAL
AZIMUTH GIMBAL
CROSS LEVEL GIMBAL BEARING
CROSS LEVEL GIMBAL
ROLL GIMBAL BEARING
DIRECTOR TRAIN DIAL
LEVEL GIMBAL BEARING
DIRECTOR TRAIN GIMBAL
DIRECTOR TRAIN GIMBAL BEARING
DIRECTOR TRAIN GIMBAL SLIP RING ASSEMBLY
BINNACLE
COVER CLAMP
MOUNTING LUG

170.27

Figure 7-17. — Stable element Mk 16, cover removed.

is basically the same as that of the Mk 6 stable element; that is, to provide a stabilized reference plane independent of ship's movement.

The stable element contains the sensitive element, gimbals, pendulums, pickoff coils, and servo mechanisms that maintain the gyro at a true vertical and generate outputs of level and crosslevel. These outputs are used in the Mk 47 computer deck tilt corrector to compute position angle and true target bearing. Crosslevel is used to keep the director stabilized in crosslevel. Level and crosslevel are sent to the rate transmitter where they are used to develop stabilization signals in elevation for all modes of operation.

Dynamic Tester and Error Recorder

The dynamic tester provides a simulated air target for the fire control system. It may be used to check the performance of the entire GFCS Mk 68, or the performance of the director power drives, the computer Mk 47, or the gun order converter.

The error recorder uses gun order and fuze order error signals from the dynamic tester to record the amount and direction of error in system or system component performance. This error is recorded on a roll of graph paper.

RELATIVE-RATE FIRE CONTROL SYSTEMS

Relative-rate fire control systems are based on gyroscopic lead-computing sights or computing mechanisms. A number of fire control systems that work on this principle are presently in use in the Navy. Most of them are generally associated with 3-inch and smaller guns although some are set up to control larger weapons also. This is in contrast to the Mk 37 and Mk 68 linear-rate systems which are primarily associated with heavier weapons. The general characteristics and principles of relative-rate gun fire control systems (especially as compared with linear-rate systems) were discussed earlier in this chapter. This section is chiefly devoted to a more comprehensive description of one such system—the GFCS Mk 56.

GUN FIRE CONTROL SYSTEM MK 56

The Mk 56 GFCS (fig. 7-18) is an intermediate-range gun fire control system primarily designed for use against high-speed subsonic targets, but usable also against surface targets. It is most commonly used with 3-inch guns, but can control 5-inch guns also. It is a dual-ballistic system - that is, it can provide elevation, train, and fuze-setting orders simultaneously to two different batteries of different calibers. It can produce a fire control solution within two seconds after tracking begins. The system is capable of either optical or automatic radar tracking in bearing, elevation, and range, and of remote control from the control room below decks. This feature provides for rapid radar acquisition of obscured targets and for blind firing (i.e., firing without visual contact).

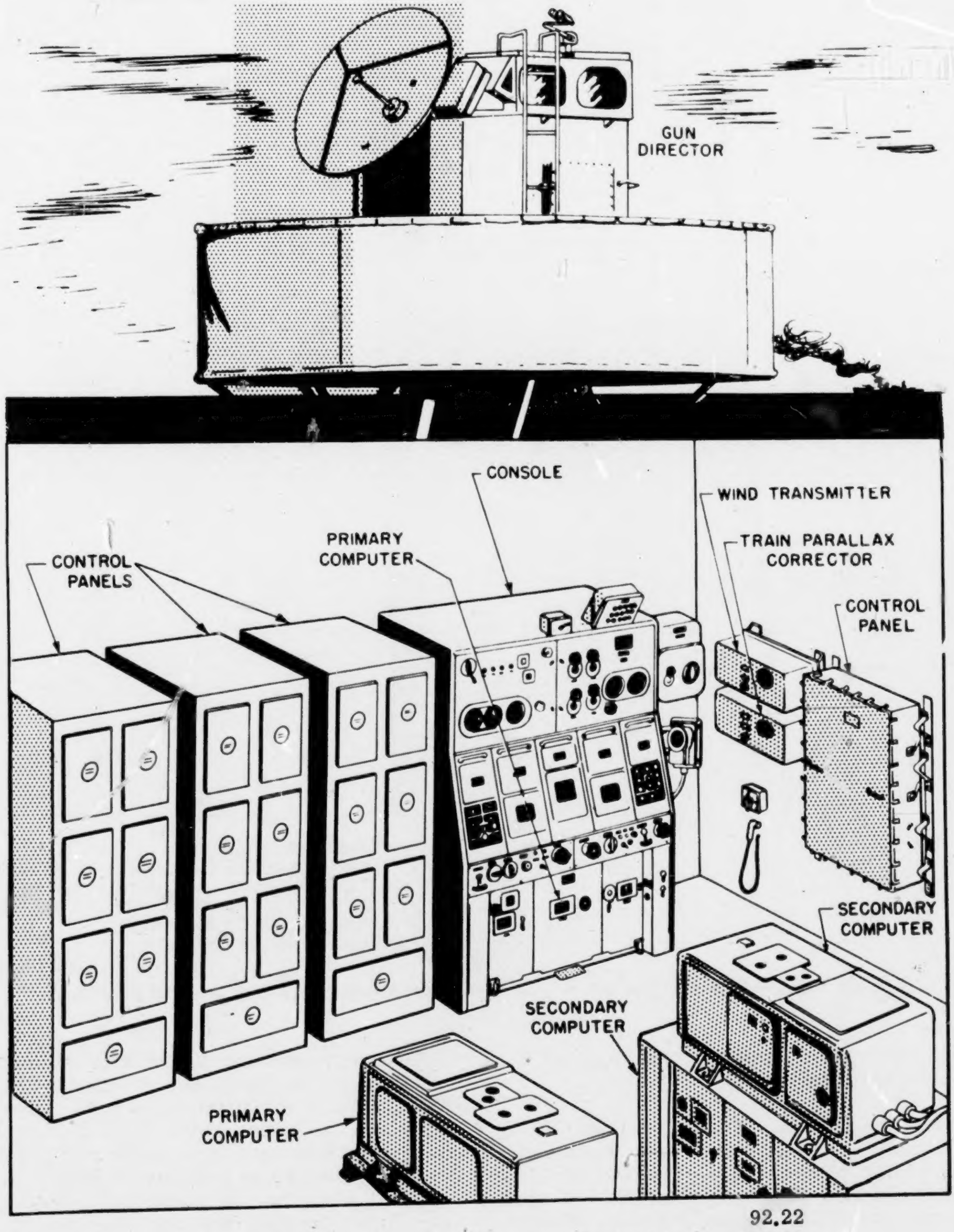
The system consists essentially of a two-axis, power-driven, direct-line-of-sight director located above decks, and various computing units located in a control room below decks. Complete radar equipment is included as an integral part of the system. The radar antenna is mounted on the director, and all radar indicators are in the control room (fig. 7-18).

The system is operated by a crew of four men, including the control officer. The latter and the pointer are stationed in the director for optical acquisition and the tracking of visible targets, and the two other men are at a console in the control room. On the console are all radar indicators and operational controls for handling range and positioning the director. Acquisition of obscured targets is accomplished from the console by matching designation dials.

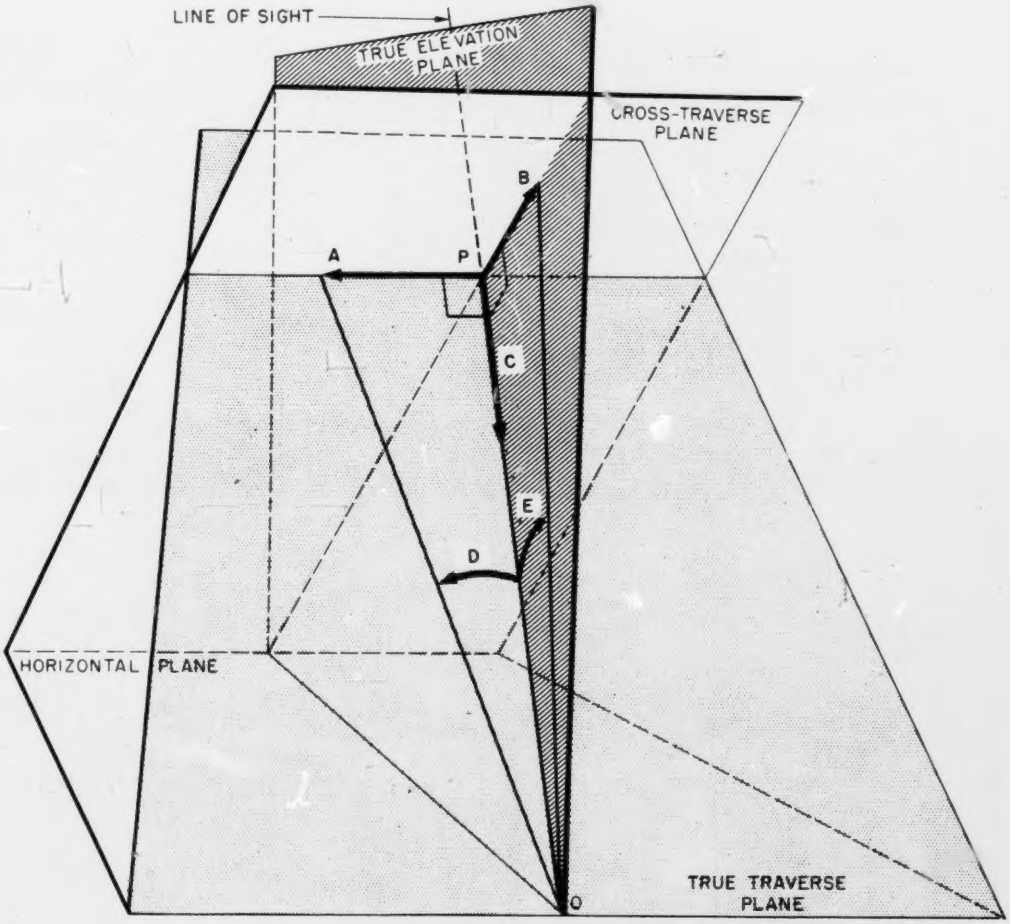
Director line of sight (including radar antenna) is stabilized by a gyro unit in the director. Computation of lead angles is based on director angular rates of motion in stabilized coordinates.

MK 56 GFCS FIRE CONTROL PROBLEM GEOMETRY

The fire control problem is expressed somewhat differently in the Mk 56 GFCS than in the linear-rate systems. Figure 7-19 shows the planes in which the values are expressed and the solution is developed in the director and computer. Two gyros in the director are used during tracking to establish the planes and values used in the solution of the fire control problem. A vertical gyro, similar to the stable element of the Mk 37 system, establishes and maintains the true horizontal and true vertical reference planes. A rate gyro precesses during tracking


GUN DIRECTOR
CONSOLE
WIND TRANSMITTER
TRAIN PARALLAX CORRECTOR
PRIMARY COMPUTER
CONTROL PANELS
CONTROL PANEL
SECONDARY COMPUTER
SECONDARY COMPUTER
PRIMARY COMPUTER

92.22
Figure 7-18.—Components of Gun Fire Control System Mk 56.



OP= PRESENT RANGE (R)
E = INSTANTANEOUS ANGULAR ELEVATION RATE
D = INSTANTANEOUS ANGULAR TRAVERSE RATE
C = INSTANTANEOUS RANGE RATE
AP = LINEAR DEFLECTION RATE
PB = LINEAR ELEVATION RATE

92.23

Figure 7-19. — Geometry of the Mk 56 GFCS statement of the fire control problem.

to develop angular rates proportional to the movement of the director.

The angular velocity of the LOS during tracking can be resolved into angular rates in two mutually perpendicular planes (fig. 7-19). One of these angular rates is elevation rate; the other is traverse rate. The solution, however, requires the use of linear rates of target motion, in a plane perpendicular to the line of sight at target's position. This plane is called the cross-traverse plane and contains linear elevation rate and linear deflection rate. Since the target is not moving entirely in the cross-traverse plane, the range changes at the rate of RANGE RATE measured along the line of sight. Linear elevation rate, linear bearing rate, and range rate are the three basic linear rates of target motion.

MK 56 GFCS
FIRE CONTROL PROBLEM SOLUTION

The first step in the solution of the problem is determination of target position. Target bearing and elevation are measured by the director. As the target is tracked, director train and director elevation are measured and transmitted by synchros to the computer. Target range is measured by radar and transmitted automatically to the computer.

Tracking the target is done either optically or by radar. A tracking control unit and telescope on the director are used for optical tracking. In automatic radar tracking, the tracking signals originate in the radar equipment, and are accurate within one-half mil.

The primary purpose of the vertical gyro is to establish a stable reference plane called the true traverse plane (fig. 7-19). It also measures true elevation of the director line of sight above the horizontal, and cross-traverse angle. Like crosslevel, cross traverse is motion about the line of sight due to movement of the deck, but cross traverse is measured in the cross-traverse plane, which is perpendicular to the line of sight, and therefore differs from crosslevel. The values of true elevation and cross-traverse angles are picked off electrically and are transmitted to the computer, where they are used in calculating ballistic corrections and gun orders. Cross traverse also goes to the cross-traverse drive gear of the rate gyro.

The rate gyro controls the drive motors that position the director in train and elevation. It does this by measuring the angular rates of target motion in the forms of electrical tracking signals and by combining these signals with the stabilizing signals of true elevation and cross traverse from the vertical gyro. The algebraic sum of these signals is obtained in a set of pickoff coils that function somewhat like the unbrella and coil arrangement in the Mk 6 stable element discussed earlier in this chapter.

The second step in solving the fire control problem is measuring the rates of target motion. As described earlier, the target is tracked in elevation and train, and error voltages generated in the pick-off coils go to the computer as rates of target motion (angular elevation rate and angular traverse rate). As for range data, the Mk 56 director has no optical rangefinder; range information is normally supplied by radar, or it can be cranked in manually if necessary. As the radar tracks the target, changes in range (range rate) drive a tachometer generator — a generator whose output voltage is directly and accurately proportional to speed) that produces a range rate voltage signal. From these three rate signals (angular elevation, angular traverse, and range) the computer can calculate lead angles in true traverse and true elevation.

The remainder of the solution process takes place in the computer, which includes the ballistic computer, wind transmitter, parallax corrector, and gun order converter, with associated amplifiers. Computations are performed by electrical and mechanical networks distributed among these units. Any of these units or all of them together may be considered as the computer.

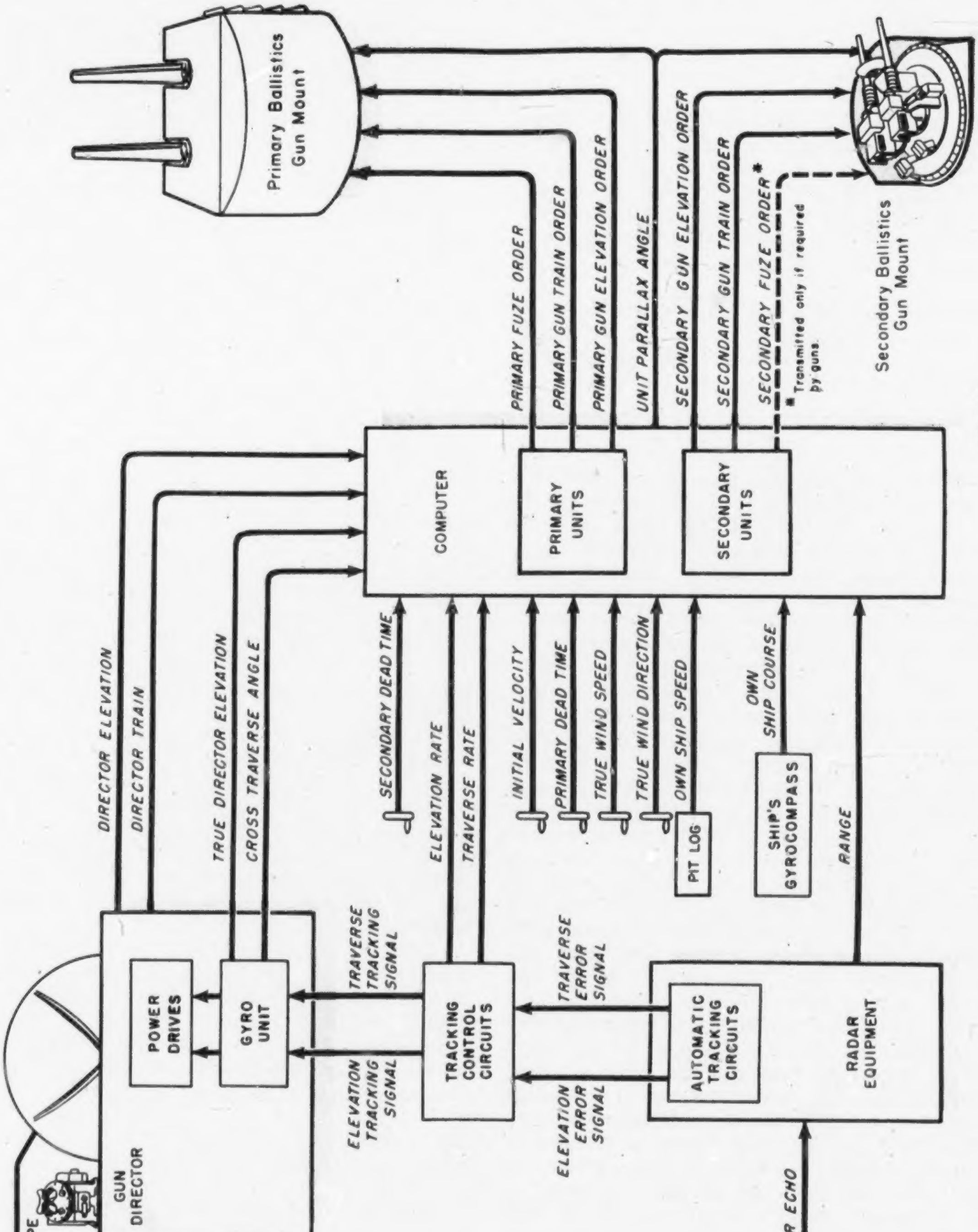
From present target position and the rates of target motion the computer calculates superelevation and drift. To correct for wind, the computer receives by synchro own ship course from the ship gyro compass, and manually introduced values of true wind speed, true wind direction, and own ship speed. Initial velocity and dead time are also cranked in manually. Ballistic corrections are computed in terms of rates. Angular rates (elevation and traverse) from the director are multiplied by range to give linear rates of elevation and deflection. The linear rates are corrected and used to calculate superelevation and other prediction quantities.

The Mk 56 system's geometry is based on the true elevation and true traverse planes as described earlier, but gun orders must be expressed in deck coordinates. The computer therefore converts the computed lead angles to deck coordinates. Additional computer units simultaneously convert these values to produce gun orders for another battery of a different caliber.

Finally, parallax correction must be made. Parallax correction is in principle similar to that already described for linear-rate systems, with standard horizontal correction computed on a 100-yard base and converted at each mount to the proper value. The Mk 56 system also computes vertical parallax correction.

Mk 56 GFCS
Summary of System Operation

Figure 7-20 shows the flow of basic quantities in the system when using automatic radar tracking (the usual method of operation). Radar receives target echoes from the antenna and transmits traverse and elevation error signal to the gyro unit as tracking signals, and to


Primary Ballistics Gun Mount
PRIMARY FUZE ORDER
PRIMARY GUN TRAIN ORDER
PRIMARY GUN ELEVATION ORDER
UNIT PARALLAX ANGLE
SECONDARY GUN ELEVATION ORDER
SECONDARY GUN TRAIN ORDER
SECONDARY FUZE ORDER*
* Transmitted only if required by guns.
Secondary Ballistics Gun Mount
COMPUTER
PRIMARY UNITS
SECONDARY UNITS
DIRECTOR ELEVATION
DIRECTOR TRAIN
TRUE DIRECTOR ELEVATION
CROSS TRAVERSE ANGLE
SECONDARY DEAD TIME
ELEVATION RATE
TRAVERSE RATE
INITIAL VELOCITY
PRIMARY DEAD TIME
TRUE WIND SPEED
TRUE WIND DIRECTION
OWN SHIP SPEED
PIT LOG
OWN SHIP COURSE
SHIP'S GYROCOMPASS
RANGE
GUN DIRECTOR
POWER DRIVES
GYRO UNIT
TRAVERSE TRACKING SIGNAL
ELEVATION TRACKING SIGNAL
TRACKING CONTROL CIRCUITS
TRAVERSE ERROR SIGNAL
ELEVATION ERROR SIGNAL
AUTOMATIC TRACKING CIRCUITS
RADAR EQUIPMENT
TELESCOPE
RADAR ECHO

53.116

Figure 7-20.—GFCS Mk 56 Simplified data flow schematic.

the computer as rates of target motion. Signals from the optical tracking control unit in the director may be selected in place of radar. The radar equipment transmits range and range rate to the computer during both radar and optical tracking.

In the gyro unit, tracking signals are combined with stabilizing signals to control the director power drives. As the director tracks the target, director position is measured by synchros, and director train and elevation are transmitted to the computer. The gyro unit also transmits values of true director elevation and cross-traverse angle to the computer.

Own-ship course is introduced to the computer electrically, while own ship speed, true wind speed and direction, initial velocity, and dead time are introduced manually. The computer calculates lead angles and ballistic corrections. The secondary computers make up and transmit gun elevation order, gun train order, fuze time order, and unit parallax correction. Within two seconds of the start of steady tracking (either optical or radar), the computer is producing accurate gun orders.

OTHER RELATIVE-RATE SYSTEMS

There are several relative-rate fire control systems used in the Navy. None, however, are used as extensively as the Mk 56 system discussed earlier in the chapter. Some, such as the Mk 63 and Mk 87 (discussed separately later), are used to a lesser degree than the Mk 56 system, and some (such as Mk 52 and Mk 57) are almost nonexistent. We will explore only the Mk 63, Mk 86, and Mk 87 systems.

MK 63 GUN FIRE CONTROL SYSTEM

The Mk 63 system (fig. 7-21) is designed to control 40-mm and 3"/50 guns and is equipped to deal with air targets from 800 to 7,000 yards range, moving with speeds up to 800 knots. The major units in the system are

1. Lead computing sight

2. Director pedestal (on which the sight is mounted)

3. Radar equipment (with the radar antenna located on a gun mount)

4. Wind transmitter — actually a computer which calculates and introduces wind correction into the system. Its inputs are own-ship course, gun train order, own-ship speed, wind direction, and wind speed.

5. Target acquisition unit (TACU). This unit aids the sight pointer in locating the target when visibility is poor or there are many targets in sight.

The director operator tracks the target manually (the director has no power drive) by training and elevating the lead computing sight on the director and keeping the target image centered in the reticle. The lead angle generated by the sight is transmitted to the gun mount power drive, so that the guns will lead the target. Lead angle is also transmitted to the radar antenna's independent power drive on the gun mount, but here it is applied to cause the antenna axis to lag the gun bore axis by an angle equal to the lead angle. The result of this, of course, is that the radar antenna is always aimed at the target.

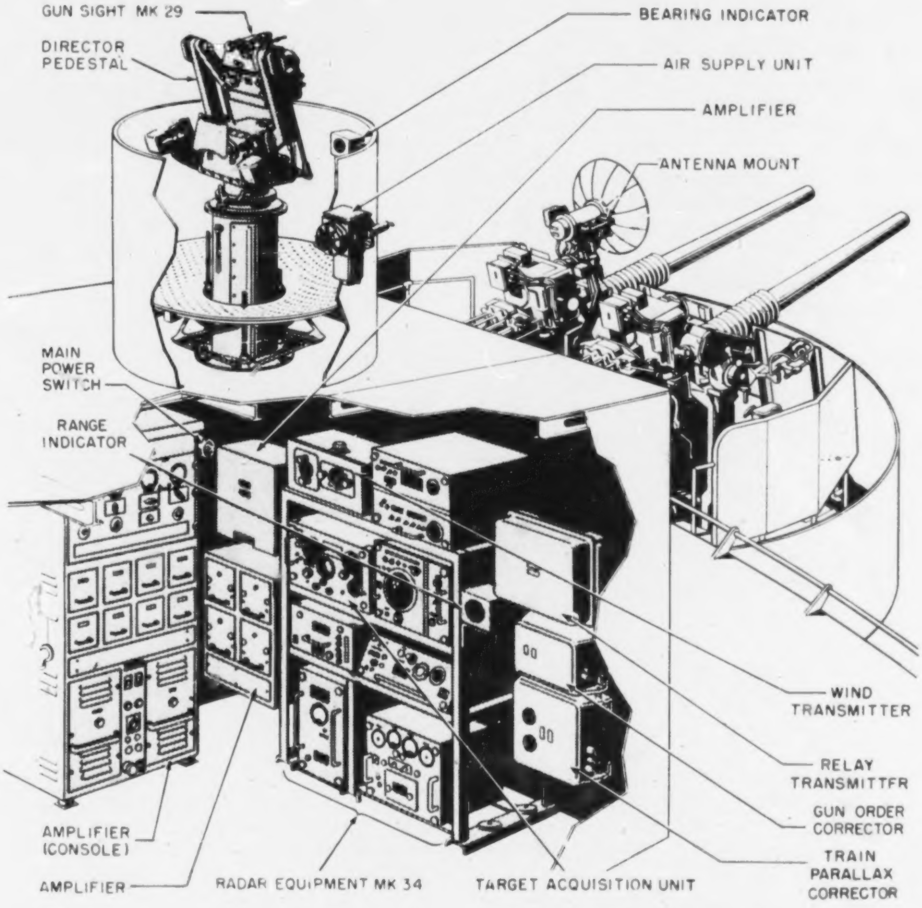
MK 86 FIRE CONTROL SYSTEM

The Mk 86 fire control system is designed to control lightweight 5"/54 guns and other weapons against surface, shore, and air targets. The system is very flexible; it can — with minor changes — be adapted for use with a variety of weapons against all type targets. Some mods function with guided missile systems in the controlling of semiactive homing missiles such as TARTAR.

The Mk 86 system has operating modes to cover just about all possible conditions of readiness. It can operate in (1) Radar Surface Fire, (2) Visual Surface Fire, (3) Indirect Shore Bombardment (with or without a beacon), and (4) Air Action radar, visual, or a combination of both. Three men, a control officer and two gun controllers, operate the system from below decks. On ships with single gun installations, one gun controller's console (and thus one gun controller) is eliminated. Components of the Mk 86 fire control system are shown in figure 7-22.

MK 87 FIRE CONTROL SYSTEM

One of the most recent developments in gun fire control is the GFCS Mk 87. It is a dual-purpose, lightweight system designed to control 3"/50 and 40 mm guns. Like the Mk 86 system, it can easily be modified to control larger guns.


GUN SIGHT MK 29
DIRECTOR PEDESTAL
BEARING INDICATOR
AIR SUPPLY UNIT
AMPLIFIER
ANTENNA MOUNT
MAIN POWER SWITCH
RANGE INDICATOR
WIND TRANSMITTER
RELAY TRANSMITTER
GUN ORDER CORRECTOR
TRAIN PARALLAX CORRECTOR
AMPLIFIER (CONSOLE)
AMPLIFIER
RADAR EQUIPMENT MK 34
TARGET ACQUISITION UNIT

53.115
Figure 7-21.—Mk 63 GFCS, major units.

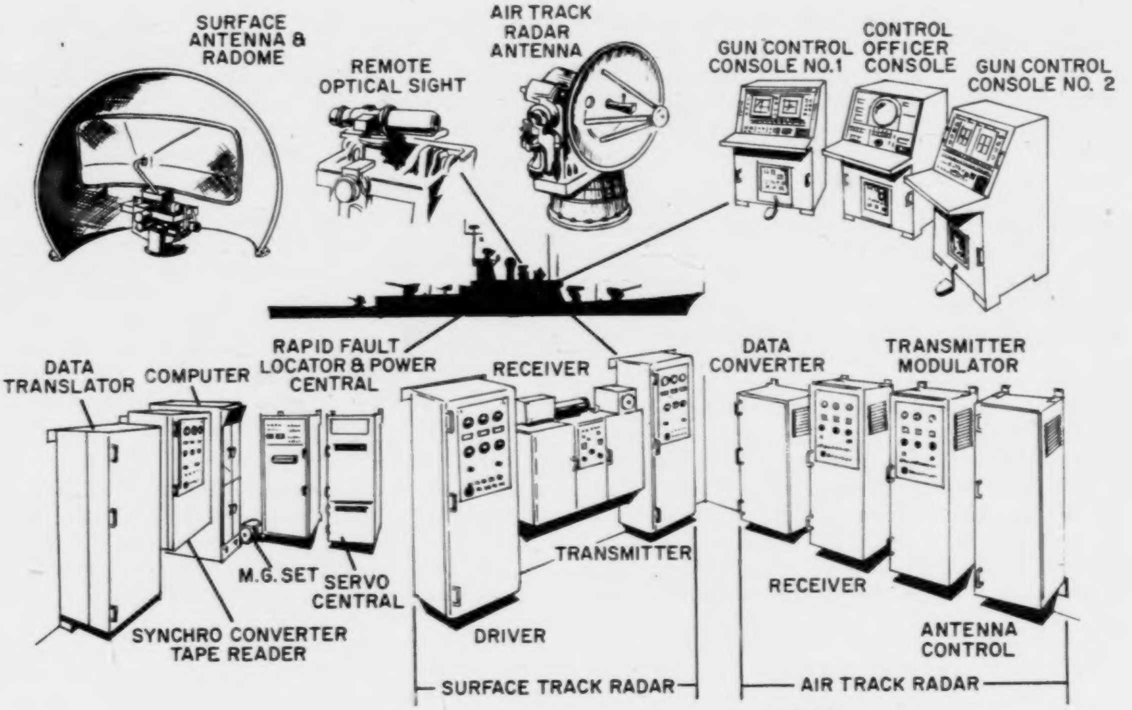
In its principal operating modes, all system functions are automatic from the time of target designation to system ready to fire. The components of this system were designed to operate as a balanced and completely integrated weapon control system. The system is self-contained and has three operators—two at the fire control console and one at the optical sight topside.

Of the two manned stations, the fire control console is the heart of the Mk 87 system. It houses the computer (a solid-state digital machine), displays, and control panels. The optical sight, the other manned station, is mounted on a stabilized platform located topside. It comprises various components including gear trains, servomotors, synchros, and a binocular mount for optical tracking and visual observation.

The system can engage two targets simultaneously. It can engage two surface (or shore targets) or one air target and one surface target at the same time.

SURFACE FIRE CONTROL SYSTEMS

Surface fire control systems are used to direct the fire of turrets. Most ships having these systems (cruisers and battleships) are in the reserve fleet. These systems are designed to control guns of 6-inch caliber and larger. They are, in general, similar to the Mk 37 linear-rate system. They are rangekeepers instead of computers and stable verticals instead of stable elements. For purposes of this book, these are


SURFACE ANTENNA & RADOME
REMOTE OPTICAL SIGHT
AIR TRACK RADAR ANTENNA
GUN CONTROL CONSOLE NO.1
CONTROL OFFICER CONSOLE
GUN CONTROL CONSOLE NO. 2
DATA TRANSLATOR
COMPUTER
RAPID FAULT LOCATOR & POWER CENTRAL
RECEIVER
DATA CONVERTER
TRANSMITTER MODULATOR
TRANSMITTER
M.G. SET
SERVO CENTRAL
RECEIVER
SYNCHRO CONVERTER TAPE READER
DRIVER
ANTENNA CONTROL
SURFACE TRACK RADAR
AIR TRACK RADAR

170.63
Figure 7-22.—Gun fire control system Mk 86.

differences in nomenclature rather than general function.

ASW WEAPON SYSTEMS

Functionally an Antisubmarine Warfare (ASW) weapon system includes the following elements:

1. An underwater fire control system
2. One or more types of delivery units organized as a "Battery"
3. One or more types of ASW weapons

There are several ways to classify ASW weapon systems. In this chapter we will classify them by the types of weapons used against a submarine as follows:

1. D/C Battery—a battery that employs a depth charge as its destructive weapon. A depth charge (D/C) battery uses either racks or projectors as delivery devices for the weapon. A depth charge essentially is merely a container filled with about 200 pounds of high explosive, and designed to explode at a predetermined depth. It is extremely difficult to obtain a direct hit with a depth charge; and, to be fatal, the explosion must occur within about 20 feet of the target.

2. H/H Battery—a battery that employs a 7.2 inch diameter mortar type projectile as its destructive weapon. The weapon, nicknamed hedgehog (H/H), is launched from either a stationary or a trainable projector. The projectors can fire 24 weapons in rapid sequence. Hedgehogs are mounted in groups of 24, and are fired in pairs; a salvo results in a circular pattern over the apparent position of the submerged target. This weapon has no depth setting and explodes only on contact. Because the charges have a fixed range, the pattern can be launched

successfully only when the ship reaches correct firing range.

3. Torpedo Battery—a battery that employs a homing torpedo as its destructive weapon. The weapon is launched from a three barrel torpedo launcher. The weapon receives prelaunch orders to search for and home on underwater targets.

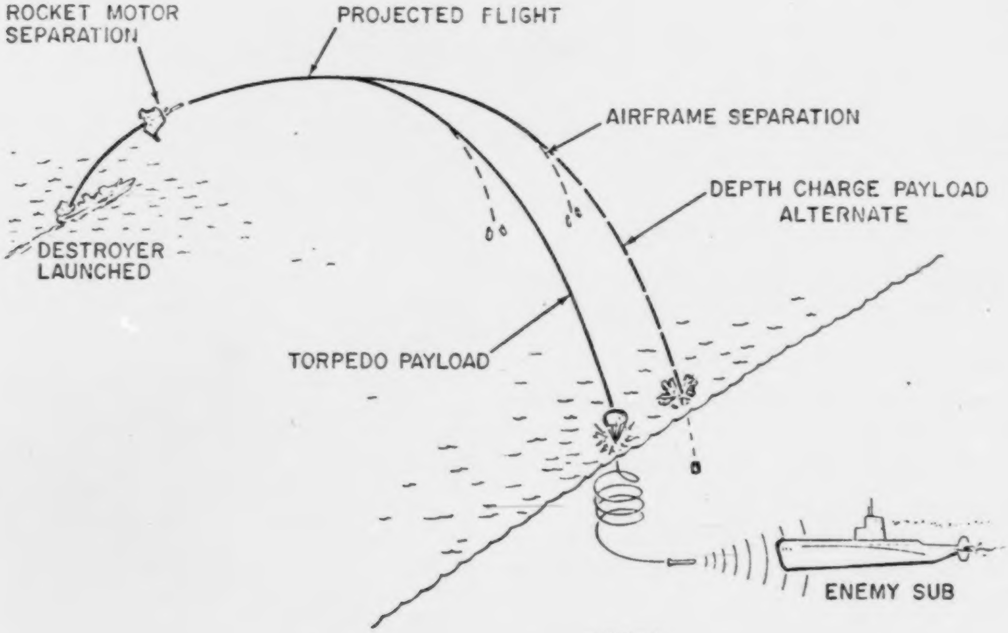
4. ASROC Battery—a battery that employs a three-stage ballistic missile as its destructive weapon. The weapon ASROC (AntiSubmarine Rocket) is launched from an eight cell launcher assembly (fig. 7-1). The weapons payload may be either a depth charge or an acoustic homing torpedo. If the payload is a depth charge, it follows a ballistic course near the target and detonates at a preset depth. If the payload is a torpedo, it dives to a preset depth and turns in a flat circle, listening for any return sounds from its own sonar transmitter. If no noise is picked up, the weapon begins a hunt pattern until a target is picked up. When a target is picked up, the hunt pattern is abandoned and the torpedo heads straight for the kill, figure 7-23.

ASW FIRE CONTROL PROBLEM

In antisubmarine warfare, the target is tracked by utilizing a series of sonar ranges and bearings to the contact. From this information and data from other sources, a course to steer and time to fire are established automatically by the underwater fire control system.

This series of events sounds simple enough and would be if the submarine remained at or near its original contact position or maintained its same course and speed at contact time. The modern submarine, however, moving at high speeds, has the ability to change course, speed, and depth. Changing its location can cause an otherwise successful attack to fail unless movement is detected in time and the solution to the fire control problem is revised to consider this change in target motion.

A modern underwater fire control system must also be tailored to the needs of the armament carried aboard a ship. Whatever the armament, the fire control system must furnish the information necessary for its aiming and firing.



15.114
Figure 7-23.—ASROC weapon.

The Mk 105, Mk 111 and Mk 114 fire control systems have proven reliable in dealing with the submarine problem. These systems receive target information from sonar and relay the information throughout the ASW weapon system, allowing the fire control system to determine the proper launch time of offensive weaponry.

Representative Underwater FCS

Because many operational aspects of specific fire control systems are classified, this section describes in general terms the functions of what may be considered a representative underwater fire control system. The description does not apply specifically to all fire control systems on all ships; the aim is to describe the main elements of most systems in order that the reader will understand their functions and how they work together.

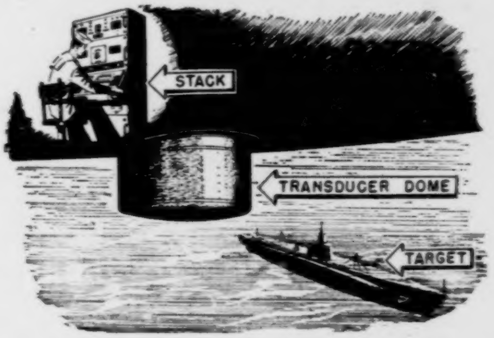
A fire control system solves the attack problem, generates launching orders, prepares a weapon for firing, develops designation data for tracking a weapon (ASROC) by radar, and provides a means for command to control weapons firing. It consists of sonar, an attack console or director, a stabilization computer, a position indicator, and one or more relay transmitters.

Sonar

Radar cannot be used under water, because water absorbs radio waves. But water does conduct sound—better than air does, in fact. And sound is what the Navy uses to detect underwater targets.

It is possible to detect a submarine operating under power by merely listening—with the aid of a suitable microphone. But present-day submarine detection equipment functions somewhat like radar—it emits a pulse of sound energy, then picks up echoes. The equipment is called SONAR—SOund NAvigation and Ranging—and it not only detects underwater targets, but also locates them in terms of range, bearing, and (in some newer equipment) depth. Let's see how sonar works on a small A/S vessel.

As you see in figure 7-24 the main units of the sonar equipment are a TRANSDUCER housed in a water-filled DOME or streamlined housing protruding from the ship's hull, and a STACK, manned by a Sonarman. The stack periodically produces a powerful pulse of alternating current, which is transmitted to the transducer. The transducer converts the current into a pulse of high frequency sound (around 20,000 cycles per second), and projects it into the water along a fairly narrow beam. The transducer then switches to receive echoes, which are amplified in the stack. However, sound vibrations of 20,000 cycles per second are ULTRASONIC—too high in pitch to be audible to people of 'normal hearing. So the stack's electronic circuits convert the echo to an easily audible 800 cycle-per-second note, which is what the Sonarman hears over the stack's loudspeaker. Bearing can be read from a dial showing the transducer's bearing. Range is obtained from a timing device which measures the length of time it takes for the sound (traveling at about 4,800 f.p.s., depending on temperature and other factors) to reach the target, and the echo to get back to the ship; range is displayed on a scale calibrated in yards.



53.117
Figure 7-24.—Elements of sonar.

With smaller ships and older installations, the Sonarman manning the stack goes through a continuous search of the underwater area about the ship. He "pings" (sends out the high-frequency sound pulse), trains through 5°, and listens; pings, trains, listens, and so on through the entire arc of train, interrupting the process only to investigate echoes. Aboard larger ships that specialize in A/S attack, such as DDs the equipment is more elaborate. The transducer pings through 360°, and the indicator presents an image of sonar echoes as blips on the face of a cathode ray tube (much as with radar PPI-scope presentation). These ships also have additional sonar equipment to determine depth of the target.

The data from the sonar stack goes to Underwater Battery Plot (usually called UB Plot), where the fire control problem is set up and solved.

Attack Console

The attack console is a computer in the data processing center of the FCS. In addition to receiving target data from sonar, it may be able to act on target bearing and range from missile or gun FC radars.

The console receives information such as (1) own-ship course and speed, and (2) target range, relative bearing, depth, course, and speed. There may be other inputs, depending upon the type of weapon to be launched; most inputs are generated electronically, while others may be inserted manually. The console displays the attack problem on the console geographic plotter section, combining target data with ballistic and own ship motion to provide (depending on the weapon to be employed) —

1. Generated data for sonar tracking and position keeping
2. Launcher train and elevation orders
3. Missile or torpedo set-in orders
4. Range and bearing for torpedo attacks
5. Director designation for in-flight tracking

From received target motion quantities the console computes aided sonar bearing and range tracking information and sends it to sonar. If sonar loses contact, the operator places the console in the position-keeping mode, and attack problem computations continue from the last observed target range, bearing, course, and speed values already entered into the computer.

Depending on what the inputs in the computer are and the weapon(s) to be controlled, the console solves the attack problem and transmits to the weapon the firing signal and the stabilized weapon train angle. It also transmits to the bridge the course to steer for the attack. (More precisely, it puts out corrections to own-ship course.)

Stabilization Computer

The stabilization computer receives roll and pitch data from the ship's gyrocompass, target bearing from sonar, and apparent depression angle from the attack console. From these quantities the computer generates stabilized sonar train and depression orders and transmits them to sonar. Input and output stabilization data are displayed on dial indicators on the front panel of the computer.

Position Indicator

A position indicator on the bridge provides command with an indication of the source of contact (sonar or radar); a continuous display of own ship, target, and weapon tactical information; an indication of firing readiness; and for some weapons a control by which the commanding officer approves the payload selection. For the last, unless command activates the "approved" control, the attack console cannot generate a firing command.

Relay Transmitters

In general, relay transmitters receive input data at a particular frequency, then convert it to a different frequency (operating voltage) for transmission to other equipments. There are many types of relay transmitters depending on the purpose for which utilized. This brief discussion is concerned only with FCS relays.

One type of relay transmitter tests, programs, and monitors the ignition and separation assembly data of a selected missile. After the missile is selected, the transmitter tests the power supply, thrust cutoff velocity time channel, and airframe separation time channel to ensure missile readiness for firing. If missile check results are unsatisfactory, another missile must be selected.

A second type makes the attack console compatible with gun or missile FCS's and weapon direction equipment. This transmitter is used during (1) missile or target tracking and (2) missile designation. For the former, the transmitter converts single-speed synchro target or missile bearing data into two-speed synchro signals for transmission to the attack console. When the transmitter is utilized for missile designation, water entry point quantities and airframe separation time are received by synchro transmissions from the attack console. Designated missile elevation is set in manually.

FIRE CONTROL
SYSTEM MK 105

Figure 7-25 schematically shows a basic underwater fire control system (Mk 105) and the A/S control stations. (Some of the weapons this system is designed to control, such as the weapon alpha, torpedo tubes, etc., are not shown.) The ship pictured carries the weapons found on the primary A/S vehicle, the destroyer.

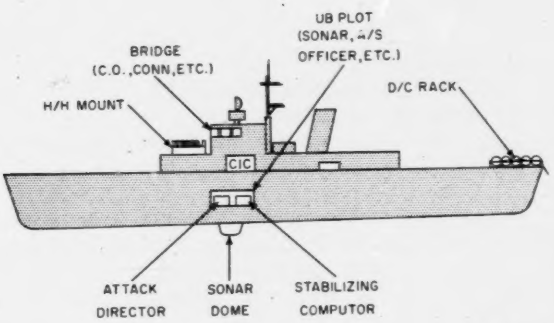


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Figure 7-25. — Major components and control stations of the Mk 105 UFCS.

This section will concentrate on the installations found on that type ship.

The major components of the system include the sonar, attack director, stabilizing computer, and the A/S weapon.

It may help you to understand this fire control system and how it works if you will consider the underwater problem as an air problem turned upside down, and the components of the underwater system Mk 105 functioning like the Mk 37 gunfire control system described previously. In doing this, you can substitute the sonar for the radar, the attack director for the Mk 1A computer, and the stabilization computer for the stable element.

The sonar locates the target and transmits target range, relative bearing, and depth to the attack director. The attack director (or computer) receives these inputs along with others such as target course, speed, and parallax, and values peculiar to A/S weapons such as depth charge or hedgehog sinking speed. The inputs actually entered depend on the type of weapon used.

The attack director solves the problem in much the same way as the Mk 1A computer does; that is, by the linear rate method. Outputs from the attack director include time-to-fire, course to steer for the attack, and stabilized launcher train angle. (The last output would be required by a trainable launcher such as weapon alpha and some H/H mounts.) The attack director transmits generated sonar range and bearing back to sonar for position keeping and aided tracking when the target contact is momentarily lost.

The stabilization computer receives ship's roll and pitch signals; it transmits stabilization signals to sonar, and to launchers that are capable of being trained or tilted.

The above setup is applicable to the system's control of three common A/S weapons — the depth charge, fixed hedgehog mount, and the trainable hedgehog mount. The system remains the same, up to a point, if called upon to solve the problem for the Mk 108 rocket launcher. In this case, the attack director's generated solution and the stabilization computer's signals go first to a ballistic computer, which adds wind inputs and pattern radius inputs. From the ballistic computer the rocket launcher receives train angle and weapon elevation. Time-to-fire signal is not necessary, because the launcher (except while being loaded) remains continuously aimed to deliver the rocket to the target location.

FIRE CONTROL SYSTEMS MK 111 AND MK 114

To successfully combat modern nuclear powered submarines with their high rate of speed, a sophisticated weapon (ASROC) and a fire control system have been developed. The ASROC weapon is used with either the Mk 111 or Mk 114 FCS. The ACROC battery is capable of launching a weapon at sufficient ranges to allow the launching ship to remain either out of the submarine's firing range or at the maximum weapon range.

The Mk 111 FCS was developed to control the ASROC Weapon System in conjunction with the AN/SQS-23 Sonar Detecting-Ranging Set. This system incorporates the elements necessary for planning, computing, and conducting an attack, and provides the launcher and missile with the data required for target destruction. Major fire control components include the following:

1. Attack Console Mk 38
2. Position Indicator Mk 78
3. Relay Transmitter Mk 43
4. Relay Transmitter Mk 44

The attack console is the data processing center for fire control in this system. It receives target range, bearing, and depth inputs from sonar or radar and combines them with own ship information to generate the commands for the ASROC launcher and missile. The console also stabilizes the launcher by correcting the order signals for own-ship roll and pitch, and for launcher roller-path inclination. Other console functions include providing information to the fire control radar to aid the radar operator in acquiring and tracking the ASROC missile after firing. This information is transmitted to radar via Relay Transmitter Mk 44.

Position Indicator Mk 78 provides the commanding officer with own-ship, target, and missile tactical information. This information is automatically and continuously displayed to provide an abbreviated but complete picture of the attack development. The Position Indicator also indicates the target contact made by sonar or radar and the firing readiness condition. Included is a control to permit approval of the payload selection (torpedo or depth charge).

Relay Transmitter Mk 43 tests, programs, and monitors the Ignition and Separation Assembly (ISA) of the ASROC missiles. These functions are performed automatically when the missile to be fired is selected. If any of the tests are unsatisfactory, another missile must be selected.

Relay Transmitter Mk 44 functions as the signal convertor between the Attack Console and the fire control radars. This transmitter converts the water entry point quantities, received from the Attack Console, into missile-acquisition signals acceptable to radar for missile tracking. The transmitter also sends a signal to the radar operator three seconds before missile airframe separation to warn the operator to expect multiple targets on his scope.

The major differences between the Mk 114 FCS and the Mk 111 FCS are in the Attack Console. The Mk 114 utilizes the Mk 53 Attack Console, which is smaller, lighter, and more flexible than the Mk 38 used in the Mk 111 FCS. The dynamics test and sonar stabilization functions of the Mk 38 are not included in the Mk 53. The dynamic test unit has been eliminated from the Mk 53, and sonar stabilization functions are performed by Stabilization Computer Mk 134. The computation within the Mk 53 is pure analog, as compared to the analog-digital methods employed in the Mk 38.

The firing panel sections of the two Attack Consoles have many differences. The Mk 53 has capabilities for selecting the mode of operation for several ASW systems; whereas the Mk 38 selects only the mode for the ASROC Weapon System. In addition to ASROC, the Mk 53 is capable of providing fire control data for Torpedo Tube Mk 32 and DASH. To handle the additional signals involved, the Underwater Battery Fire Control (UBFC) switchboard for Fire Control System Mk 114 has been enlarged from two sections to three.

The following components make up the Mk 114 FCS:

1. Attack Console Mk 53
2. Stabilization Computer Mk 134
3. Position Indicator Mk 78
4. Relay Transmitters Mk 43, Mk 44, and/or Mk 45

Stabilization Computer Mk 134 aids sonar in tracking the submarine target. It uses own ship roll and pitch, target bearing, and apparent target depression angle to generate stabilized train and depression orders for transmission to sonar. All other units function the same as those described in the preceding section. A representative Mk 114 FCS is shown in figure 7-26. As illustrated, the system receives inputs from sonar and gun fire control or missile fire control radar for computing target information. (Keep in mind that this is only a representative Mk 114 FCS; other modifications of the system may or may not have the same components as this one.)

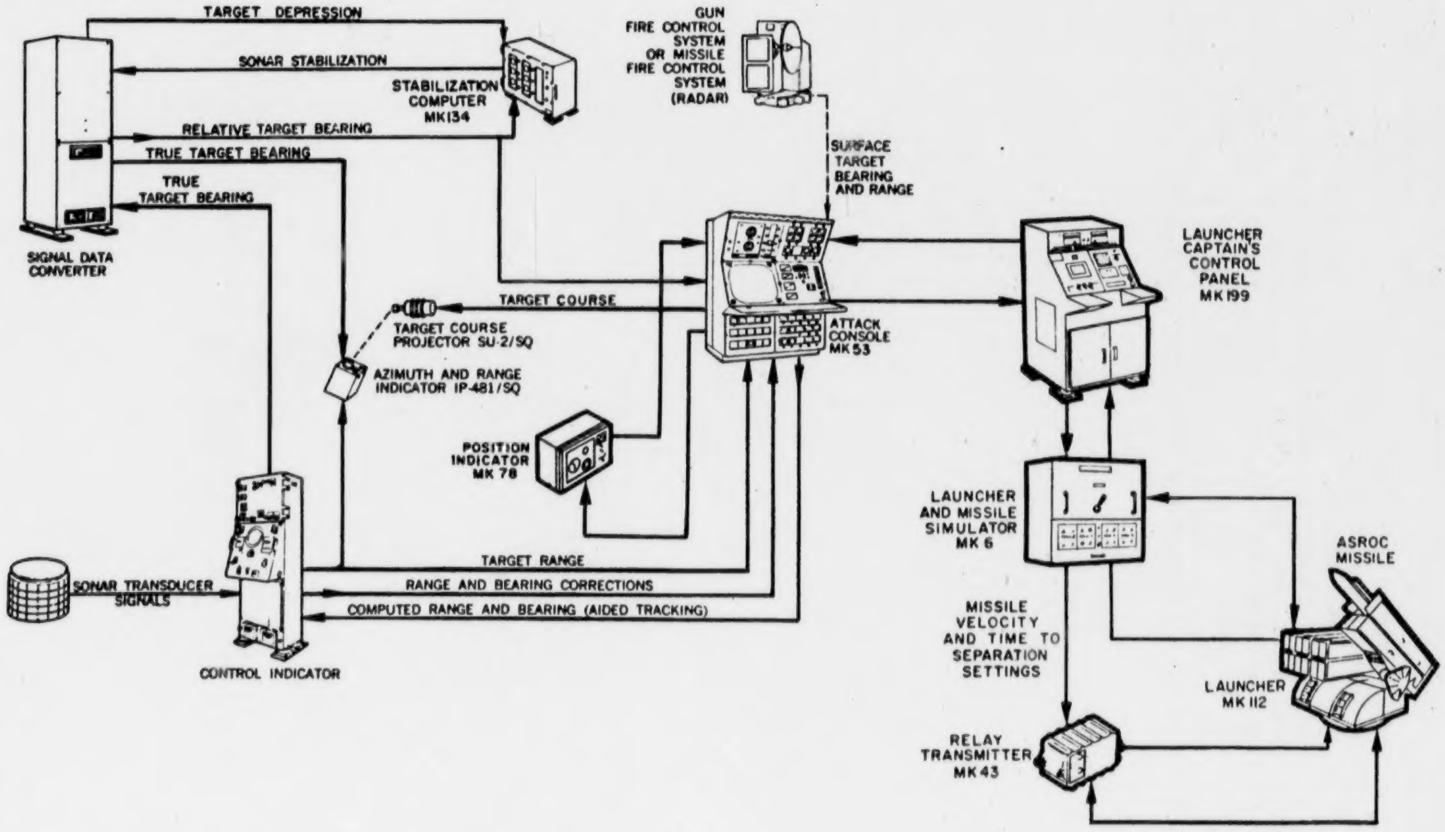
FUNCTIONS OF THE UFCS IN AN ASW ATTACK

The ASW attack is one that takes a maximum amount of cooperation between different stations. The attack team includes underwater battery plot, the sonar control room, the conning station, CIC, and the weapon mounts. They are connected by the sound-powered battle telephones.

When a contact is made, it is plotted and evaluated by CIC, which informs the captain on the bridge of the range, depth bearing, and speed of the contact. The captain decides whether to attack and which weapon to use. The sonar operator keeps the sonar on the contact at all times. The attack director operator sets up the director and sets the various inputs for the particular weapon designated. CIC maintains a track of the contact and supplies the director operator with the initial target course and speed.

The attack director operator and sonar operator work closely together until they achieve a solution and so inform the conn and CIC. Conn steers the ship along the course as directed by the attack director and gives the order to fire.

Trainable weapon mounts are automatically driven in train and will follow the solution of the attack director. CIC maintains a plot of sub movement. (CIC can be of invaluable help to underwater battery plot by keeping them


TARGET DEPRESSION
SONAR STABILIZATION
STABILIZATION COMPUTER MK134
RELATIVE TARGET BEARING
TRUE TARGET BEARING
TRUE TARGET BEARING
SIGNAL DATA CONVERTER
GUN FIRE CONTROL SYSTEM OR MISSILE FIRE CONTROL SYSTEM (RADAR)
SURFACE TARGET BEARING AND RANGE
TARGET COURSE
TARGET COURSE PROJECTOR SU-2/SQ
AZIMUTH AND RANGE INDICATOR IP-481/SQ
ATTACK CONSOLE MK53
LAUNCHER CAPTAIN'S CONTROL PANEL MK199
POSITION INDICATOR MK 78
LAUNCHER AND MISSILE SIMULATOR MK 6
ASROC MISSILE
SONAR TRANSDUCER SIGNALS
TARGET RANGE
RANGE AND BEARING CORRECTIONS
COMPUTED RANGE AND BEARING (AIDED TRACKING)
CONTROL INDICATOR
MISSILE VELOCITY AND TIME TO SEPARATION SETTINGS
LAUNCHER MK 112
RELAY TRANSMITTER MK 43

15.184:.185

Figure 7-26. — Data flow between sonar and fire control, and between fire control and ASROC (Mk 114 FCS).

informed of the direction of maneuver of the submarine.)

There are two types of ASW attacks—urgent and deliberate—and the use of one or the other depends on the tactical situation. An urgent attack is a harassing attack on a submarine and is delivered in the minimum possible time. An urgent attack is made on a submarine which is in position to menace any ship in the body of a force or formation. The urgent attack normally consists of an attack that is destructive in nature and employs all weapons that will bear. Accuracy is usually sacrificed for speed.

Preparation for a deliberate attack begins even while the urgent attack is in progress. A deliberate attack is delivered when the tactical situation allows time to obtain accurate weapon data. The most effective antisubmarine weapon required by the tactical situation is used. The deliberate attack is therefore a concentrated attack to kill. Any consideration other than the destruction of the submarine is ignored.

CHAPTER 8

BATTERY ALIGNMENT

No matter how well the elements of a gun or missile battery and their fire control systems function individually, they cannot function as a weapon system unless they are properly aligned with each other.

Alignment refers to both a condition and an action. As a condition, it indicates the relationship between the sight directions or bearings of various elements of fire control and delivery units. As an action, it refers to those operations performed to ensure that the elements are oriented and adjusted to simultaneously maintain the desired bearing relationships throughout the operating motions.

The basic objective of alignment is to ensure that the weapon lands "on target". Alignment is particularly important in a ballistic system such as gun, ASROC and rocket battery. Since these batteries receive no guidance after launch, they must be fired in the correct direction at the proper elevation to arrive at the optimum kill point. Misalignment between a battery and fire control system can result in repetitive misses; combat with high-performance targets does not always permit the luxury of a second shot. Proper alignment of a weapon system is also necessary to ensure that a weapon doesn't strike a part of the ship's structure or equipment.

Alignment of all elements of a ship's weapon system to a common reference point is "battery alignment." This process ensures that all associated gun bores, launcher line of sight, radar beams, gun sights and fire control directors are parallel when the dials and sights are matched when no parallax or ballistic corrections have been made. It ensures further that they remain parallel throughout their operating motions, and that all instrument dials and automatic control equipment measure these motions correctly with respect to the proper reference. Specific alignment data is entered in the ship's weapon system log for each delivery unit within a battery. The alignment of each battery must be checked periodically and adjusted when necessary. Figure 8-1 shows the requirements for a properly aligned battery.

BASIC TERMS

The basic terms used in this chapter, as applied to battery alignment, will be as follows:

ELEMENT. Any unit of gunfire control system, gun, director, etc.

SYSTEM. Two or more elements that operate together.

INTERNAL ALIGNMENT. Equipment within an element aligned to that element.

SYSTEM ALIGNMENT. Elements of a system aligned together or to a standard reference plane or point.

INTERALIGNMENT. One system aligned to another (secondary to primary, etc.).

OFFSET CENTERLINE. A line parallel to the ship's centerline, either on board or on the dock. Used as a reference line for measuring angles in train.

INTERNAL ALIGNMENT

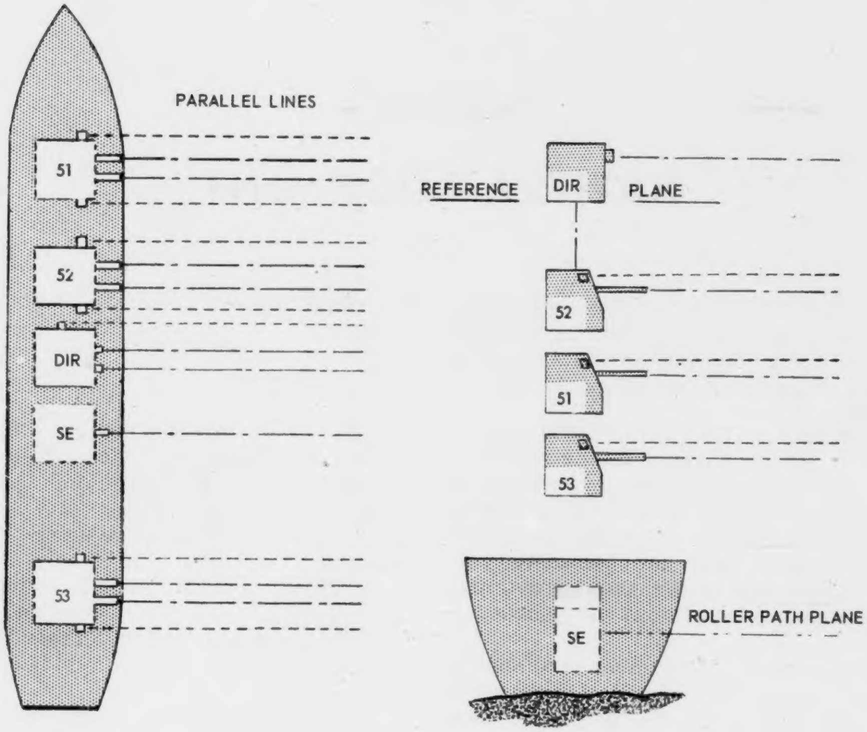
The initial responsibility for the alignment of an ordnance element within itself, such as parallelism of sights to trunnions, and parallelism of trunnion axis to the roller path plane, rests largely with the manufacturer of the element.

Onboard checks for determining any departure from correct internal alignment are described in the ordnance publication for the element.

We will assume before going any further into the procedures for battery alignment that the elements are well constructed and correctly adjusted within themselves.

LOST MOTION

The effects of lost motion, as they affect internal alignment, are to be taken care of in the course of routine repair and adjustments. When lost motion is encountered in other phases



53.120
Figure 8-1.—Requirements of a properly aligned battery.

of battery alignment, the best procedure is to take readings from opposite directions and split the error equally on both sides.

SYSTEM ALIGNMENT

System alignment may be divided into two phases: original alignment in drydock, and alignment afloat. In your work you will be concerned mostly with alignment afloat. For that reason we will not discuss the procedures for alignment in drydock in great detail. But we will explain their purpose, and show how they fit into the overall alignment picture.

ALIGNMENT IN TRAIN (IN DRYDOCK)

In the following discussion, assume that all elements of the system are properly installed and in working order, and that they are mechanically aligned within themselves.

Purpose

The purpose of battery alignment in train is to adjust the battery so that, when the dials are matched and no ballistics or horizontal parallax are introduced, the lines of sight of directors and guns, and the axes of the bores of the guns, are parallel in train at any angle of train.

Establish Offset Centerline

When in drydock, the first step in preparation for battery alignment in train is to establish a CENTERLINE from which to measure horizontal angles. In most cases, because of the interference of the ship's structure, this line will take the form of an "offset centerline" ashore, parallel to the real centerline of the ship. The centerline is established by use of surveyor's transits. OP 762, Alignment of Ordnance Installations

Aboard Ship, gives complete details on this procedure.

Next we must establish the center of rotation of each trainable element, so that a transit may be set up to measure the true angle of train of the element. The center of rotation may be located by using either the transit or the plumb-bob method.

After the center of rotation has been determined, it should be checked by sighting from a transit to assure that the calculated center does not move out of the transit line of sight when the mount is trained.

Establish Zero Train

The first step in actual alignment in train is the establishment of zero train. This consists of setting the train dials of each element so that when they read zero train, the line of sight or axis of the bore of each element is parallel to the centerline of the ship. The forward elements dials are set at 0°, with the elements pointing forward and parallel to the centerline. The after elements dials are set at 180°, with the elements pointing aft and parallel to the centerline.

The above procedure is accomplished by measuring angles with a surveyor's transit in conjunction with the reference telescope (for directors) or the boresight telescope (for mounts and turrets), using the previously established center of rotation and offset centerline as references. (The exact procedures for establishing the offset centerline and center of rotation, and for establishing mechanical zero train, are described in OP 762.)

When zero train has been established, train the elements to this position (exactly parallel to the ship's centerline). The Fire Control Technicians will adjust the dials at the director to zero, and adjust the synchro transmitters until they transmit zero train. At the mount, you will adjust the train dials to read zero and adjust the synchro receivers to electrical zero. (Remember that the methods for zeroing synchros are covered in GMG 3/2, NP 10185-A, and USN Synchros Description and Operation Handbook MIL-HDBK-225 (AS).

RECORD ZERO TRAIN.—After the zero train position has been established by taking benchmark and train tram readings, some means must be provided for reestablishing the alignment at any future time. This is necessary because the dials or synchros may become misaligned as a result of vibration and normal wear, or as a result of disassembly.

BENCH MARKS.—For purposes of checking director's zero train at sea, a benchmark and benchmark reading are established. The benchmark usually is a small brass plate with cross-lines etched on it. This plate is welded to a secure part of the ship within vision of the director's sights. After zero director train has been established and the dials set, train the director and put the crosswires of the pointer's telescope on the benchmark, and read the train angle-reader dials. This is the benchmark reading which should be recorded, and which will remain the same until such time as new drydock data are obtained. The same telescope must be used for obtaining all settings and readings.

TRAM READINGS.—A reference point for each turret or mount must be established in order to check the accuracy of gun train dials at sea. The original tram readings are taken after zero mount train has been established and the dials set. However, unlike benchmark readings, which never change, tram readings will change each time response is broken and any alignment correction made to the mount. New tram readings must be taken and recorded after making any alignment correction between mount and director. The procedure for tramming is covered in an earlier book of this series, and will not be repeated here. However, if the mount you are tramming is equipped with parallax, be sure it is set on zero before you take tram readings.

ALIGNMENT IN ELEVATION (IN DRYDOCK)

After battery alignment in train comes alignment in elevation. The purpose of alignment in elevation is to adjust the battery so that at any angle of train, and at any angle of elevation, the lines of sight of the directors, gunsights, and the axes of the bores of guns will all be elevated by exactly the same angle above a common reference plane. (Again we assume no vertical parallax or ballistic correction, and we assume that the dials are matched.)

Before the elevation alignment of the system is started, a thorough transmission check should be held to make sure that the synchro transmission system is functioning correctly.

Taking Roller Path Data

The first step in performing the elevation alignment in drydock is to take roller path data for all elements in the system. This data will consist of a number of inclinations of each element's roller path plane with respect to the horizontal plane, measured at various train angles. The data is analyzed to obtain the tilt of each element's roller path plane with respect to the reference plane so that roller path tilt corrector settings may be determined. After the tilt correctors are set, the roller path plane of each element will be effectively parallel to the reference plane.

Since the relative tilts of roller paths might change when the ship is floated, the roller path alignment accomplished in drydock is not necessarily the final alignment. It is, however, a preliminary step to ensure that the installation will be aligned as closely as possible before alignment afloat is undertaken.

THE GUNNER'S QUADRANT.—When the ship is in drydock, roller path data is taken with a gunner's quadrant. Later, when afloat, the readings of gun mount roller path inclination will be compared with the reference plane to determine the actual final setting of roller path compensators.

There are two types of gunner's quadrants presently in use: the vernier type Mk 3 Mod 1 (fig. 8-2) and the drum type Mk 7 (fig. 8-3).

A gunner's quadrant is basically similar to a carpenter's level, but it is more precise. It is provided with an arc for measuring the angle of inclination. The vernier type is read from a conventional vernier scale, and the drum type from a micrometer drum-mounted on the shaft of the tangent screw.

To measure an element's inclination from true horizontal, follow these steps:

1. Secure the quadrant to some smooth surface on the gun so that the line of the quadrant is parallel to the axis of the gun bore and the pivot of its arm is forward.
2. Elevate the gun to some convenient angle this will make all readings positive, and eliminate working with both plus and minus readings. The difference between the readings is all that is important, so the amount of elevation is immaterial. (If the quadrant is mounted on a surface that cannot be elevated, shim it up in front.)
3. Train the gun to 0°, level the bubble and read the quadrant. Repeat this procedure at intervals of train until the element has been trained 360° or has reached the train limit. Train intervals of 30° will serve for most elements which can train through a full 360°. For elements limited to smaller sectors or where greater ease in plotting and fairing the data curve is desired, train intervals of 10° or 15° may be used. For each train interval, record the quadrant reading opposite the train dial reading.

A set of typical roller-path data is shown in table 8-1. Note that all readings are positive: quadrant was slightly elevated to avoid negative numbers.

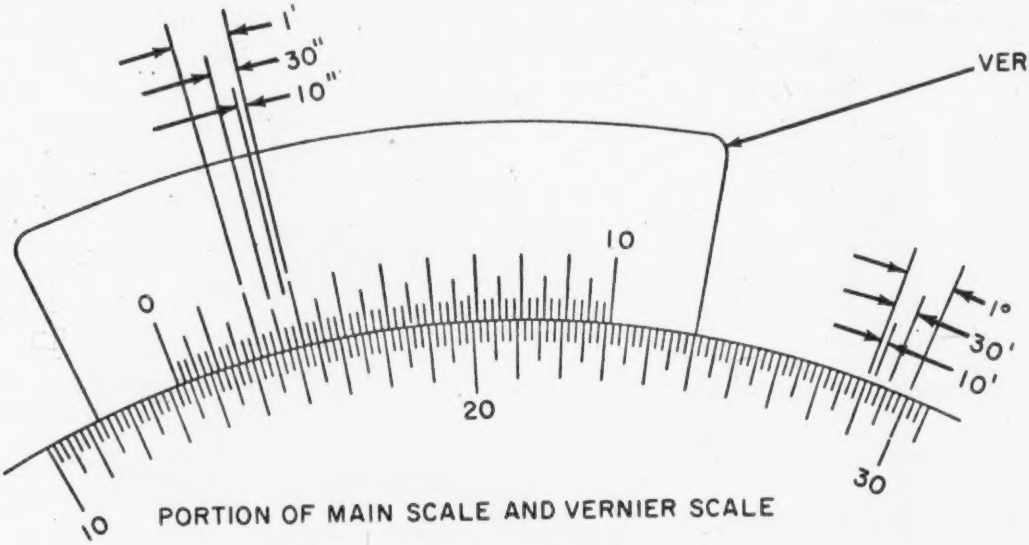
The high point can occur at any bearing angle, and probably will not be at one of the bearings at which you have taken readings. For that reason (and others that we won't go into here) the data should be plotted on a graph. The resulting curve will show the magnitude of the tilt at the high point, and the bearing at which it occurs.

The yard force will usually plot the graphs. But if you have to do this work yourself, read the instructions in OP 762, Alignment of Ordnance Installations Aboard Ship.

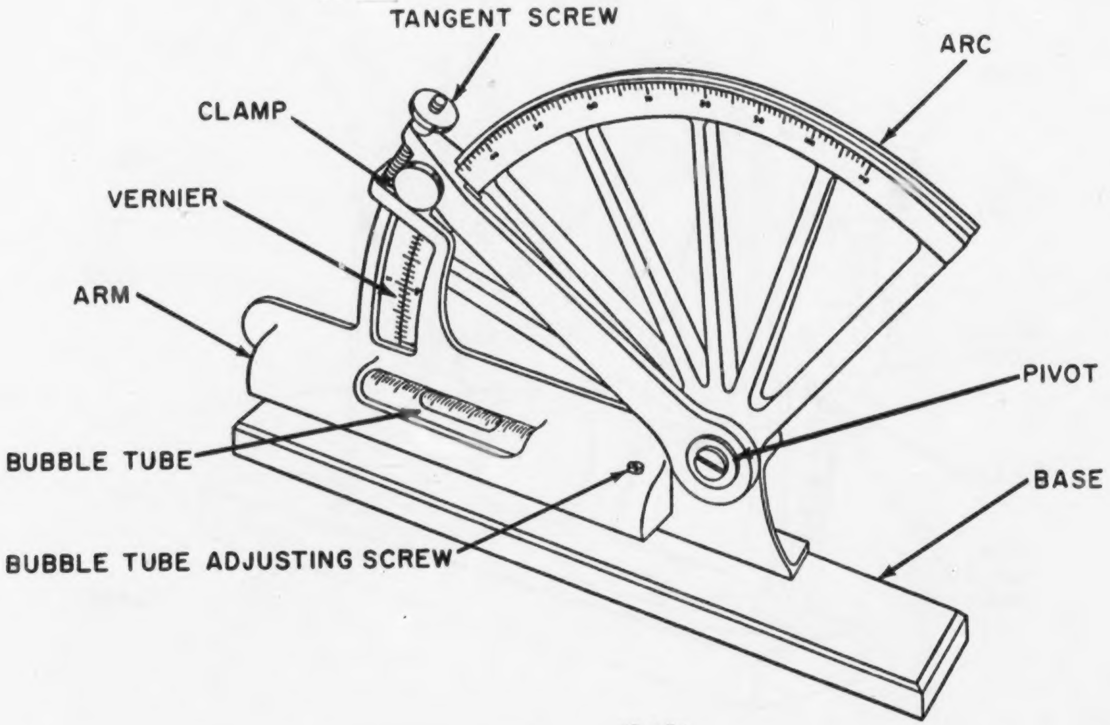
Don't forget that roller path inclination obtained with the gunner's quadrant shows roller

Table 8-1. — Typical Roller-Path Data

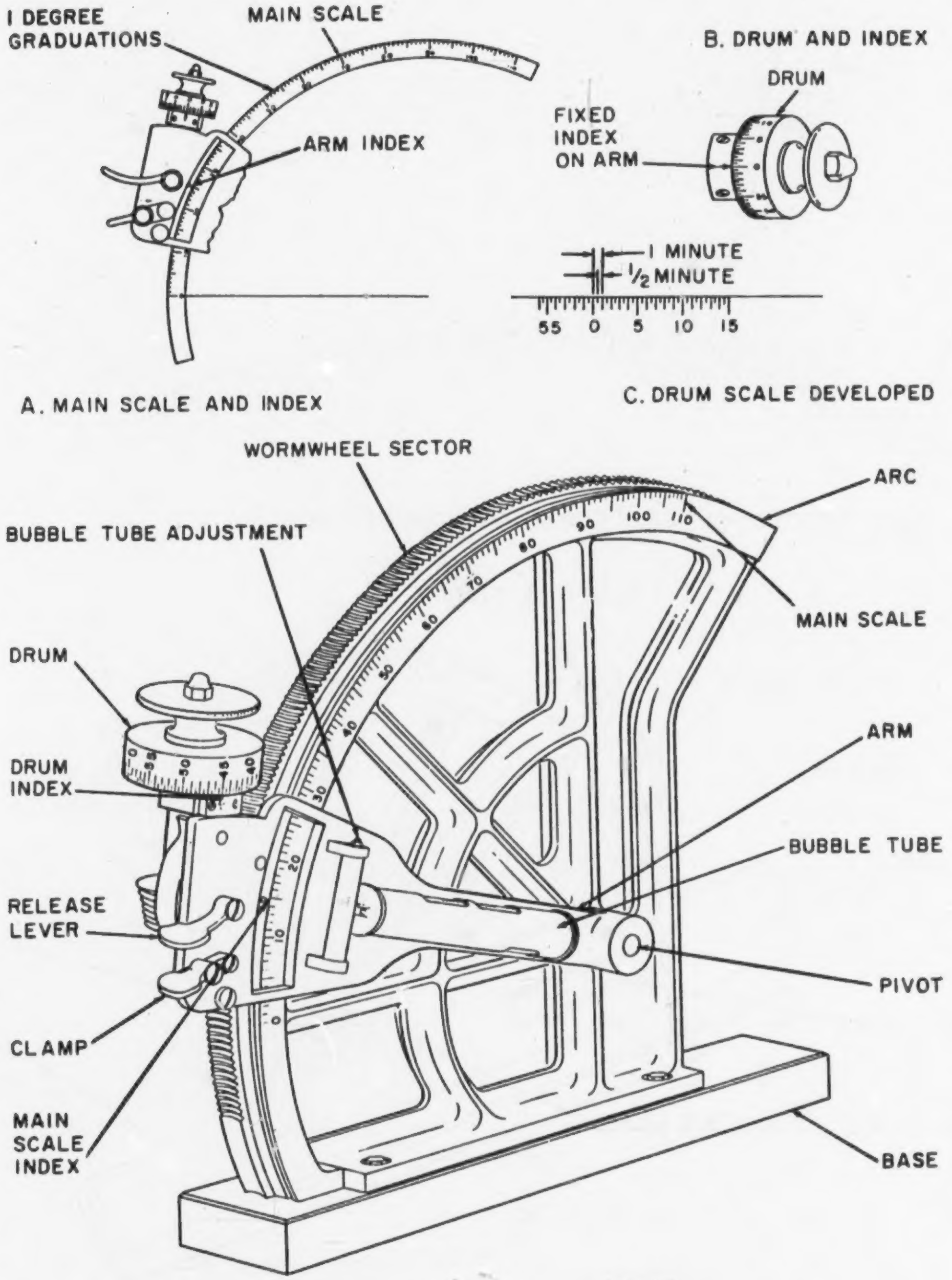
Train Angle (bearing)	Inclination From Horizontal
0°	2° 30'
30°	2° 40'
60°	2° 47'
90°	2° 50'
120°	2° 47'
150°	2° 40'
180°	2° 30'
210°	2° 20'
240°	2° 13'
270°	2° 10'
300°	2° 13'
330°	2° 20'
360° (0°)	2° 30'


1'
30"
10"
VERNIER
0
10
20
10
30
1°
30'
10'

PORTION OF MAIN SCALE AND VERNIER SCALE


TANGENT SCREW
ARC
CLAMP
VERNIER
ARM
PIVOT
BUBBLE TUBE
BASE
BUBBLE TUBE ADJUSTING SCREW

53.121
Figure 8-2. — Gunner's quadrant Mk 3 Mod 1 (vernier scale type).



A. MAIN SCALE AND INDEX

B. DRUM AND INDEX

C. DRUM SCALE DEVELOPED

I DEGREE GRADUATIONS
MAIN SCALE
ARM INDEX
DRUM
FIXED INDEX ON ARM
1 MINUTE
1/2 MINUTE
55 0 5 10 15
WORMWHEEL SECTOR
ARC
BUBBLE TUBE ADJUSTMENT
MAIN SCALE
DRUM
DRUM INDEX
ARM
BUBBLE TUBE
RELEASE LEVER
PIVOT
CLAMP
MAIN SCALE INDEX
BASE
0 10 20 30 40 50 60 70 80 90 100 110

53.122
Figure 8-3. — Gunner's quadrant Mk 7 (drum type).

path tilt above true horizontal; but what is needed to set the roller path compensator is the amount of tilt with respect to the reference plane.

Reference Plane

The reference plane is an actual plane on the ship; that is, it is the plane of the roller path of one of the elements of the battery. Ideally, the plane chosen should have the smallest possible inclination between it and the mean roller path of the other elements of the battery.

On destroyers, the roller path of the Mk 37 director is ordinarily used as the reference plane. This is because the Mk 37 director, unlike the 5-inch mounts, has no roller path compensator . There are several factors that affect the choice of the reference plane. It is usually specified in the ship's fire control doctrine.

After the reference plane has been chosen it is necessary to determine how much each element is tilted with respect to the reference plane at various bearings. These measurements are usually made by the yard force. If you want to know the details, you will find them in OP 762.

Briefly, the yard force determines the relative tilt between the gun and the director (reference plane) by a simple mathematical method. Since tilt is expressed in terms of a magnitude and a direction, it can be represented on a polar coordinate graph as a vector.

With one vector representing the tilt of the reference plane and another representing the tilt of the gun's roller path, the resultant relative tilt between the two can be plotted. The resultant relative tilt will be the basis for setting the roller path compensator on the gun. Two more alignment steps must be accomplished, however, before actually setting the compensator.

Establishing Zero Elevation of Reference Element

The purpose of this step is to position the director (reference element) so that, in elevation, it is zero degrees above its own roller path. When the director is so positioned, its elevation indicating dials and synchros are set to zero. Benchmarks can then be established for the director to provide for zero elevation alignment in the future. This work is not your responsibility; therefore, it is unnecessary to go into the details. We will assume that this work has been done correctly, and that the director's zero-degrees elevation position has been established.

Establishing Zero Elevation For the Gun

The purpose of this step is to set the gun so that its pointing lines are parallel to its own roller path plane, and then to set its dials and synchros to zero. The procedure, using a gunner's quadrant and the previously taken roller path data, is outlined in OP 762.

For the purposes of this chapter it is sufficient only to locate this step in the logical order of the alignment procedures.

After zero elevation for the mount has been established, tram readings can be taken and recorded. These readings may be used to check dial accuracy until future alignment adjustments are made.

Setting The Roller Path Compensator

Now, with the elevation dials in the gun and director reading the mean elevation of that element above its own roller path, the elevation differences due to different train angles can be corrected by the roller path compensator. When the compensator is correctly set, the gun's elevation will match the director's above the common reference plane.

Remember this phase alignment is normally conducted by other than shipboard personnel. We will describe the detailed procedure for setting the roller path compensator later in this chapter. This concludes the procedure for original alignment in drydock.

SYSTEM ALIGNMENT AFLOAT

Alignment work done while the ship is afloat consists principally of tests and adjustments required to keep the ship's ordnance equipment in readiness to deliver fire of maximum effectiveness.

Alignment work afloat is necessary because the ship's hull is a flexible structure. It is subject to small but significant changes in shape when it leaves the drydock. These changes in hull shape can cause appreciable changes in the alignment of a battery. For this reason, the alignment in drydock is only a preliminary alignment step, to make the final afloat alignment easier.

Since alignment afloat is intended to produce the same condition as drydock alignment, the general procedures are similar. However, the details of the procedures afloat are considerably different because the ship is in motion, and instruments and references on shore cannot be used.

Preliminaries For Alignment In Train

The purpose of battery alignment in train afloat is to ensure that, when the director is trained to any point and the gun dial pointers are matched (with zero settings of sight deflection and parallax), the director and gun lines of sight and the gun bore axis are all parallel in train. Since the ship is now afloat, it is impracticable to use multiple targets to obtain parallelism between the gun and director. However, if the lines of sight of both director and mount and the axis of the gun bore are aligned on a target at infinitive range, for all practical purposes they will be parallel. This method, commonly called "shooting the moon," is the most accurate method of train alignment afloat.

We will not describe all the procedures of battery alignment that apply to the many different types of ships. However, if you understand the following procedures, which are based on a typical destroyer you shouldn't have much difficulty on any other type of ship.

We should mention here preliminary checks which must be made before any alignment afloat work is undertaken. These are the elements internal alignment checks and transmission check. Synchro and dial errors corrected at this point will keep you from compounding the errors, or introducing errors to correct for errors in the ensuing alignment procedures. (Of course these errors, even if initially undetected, would be revealed before you completed your alignment work. But by then you would be faced with the task of redoing one or more of the alignment phases.)

TRAIN ALIGNMENT OF 5"/38 MOUNT TO MK 37 DIRECTOR.—The purpose of this alignment phase is to ensure that the axes of the gun bores are aligned with the director's line of sight. For maximum accuracy, use the borescope rather than the mount's telescopes. Check only one mount at a time.

This alignment should be done while the ship is tied up. But it may be done while the ship is at anchor or underway if the sea is very calm and holding a steady course. Use a target at infinitive range. You can use either the moon or an easily identifiable star, at an elevation of 30° or less.

Procedure for Conducting Train Alignment.—Before conducting train alignment the director must be checked on its benchmark. The Fire Control Technicians will conduct this check and if necessary, make any adjustments to the director's dials and synchros. Then the following steps will be taken.

1. At the mount:
    a. Put parallax in "manual" and set on zero.
    b. Install the borescope in the left gun of a twin mount, or in the gun of a single mount.
    c. Station the pointer, trainer, and boresight operator in the mount, with the boresight operator manning the JP telephones.

2. Station a recorder in plot on JP telephones. Director pointer and trainer take stations and also man the JP telephones.

3. Train the mount and director near the target. Shift the mount and director to manual drive and train the mount and director on target in the same direction.

4. The boresight operator in the mount calls "Mark" over the JP telephones as the vertical crosswire of the borescope is on the target.

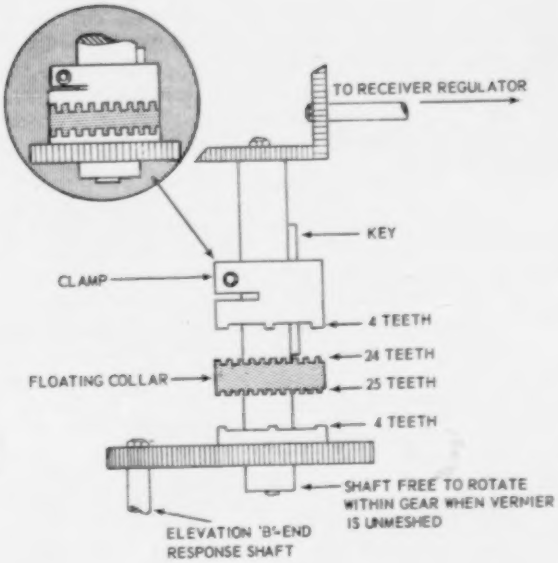
5. Director trains in manual until the vertical crosswire of the pointer's telescope is on at the mount's mark.

6. When the director is on at the mark, the recorder in plot records the mechanical dial readings of both the mount and director as received over the JP telephones. Do this at least 5 times.

7. Train the mount and director on target from the opposite direction and repeat the procedure at least 5 times.

8. Average all the director train readings. Then average all the mount train readings. The difference between mount and director train readings is the alignment error. Be sure to note the direction of the error. No alignment error exists if there is no difference in train readings, when on a target at infinite range with parallax on zero. The allowable error tolerance is plus or minus 2 minutes.

Procedure for Correcting Train Alignment Errors.—Before we correct for train errors, locate the train response adjustable coupling (cover No. 2 for twin mounts) in the train handwheel bracket assembly of the mount (fig. 8-4). Then proceed as follows:


TO RECEIVER REGULATOR
KEY
CLAMP
4 TEETH
24 TEETH
FLOATING COLLAR
25 TEETH
4 TEETH
SHAFT FREE TO ROTATE WITHIN GEAR WHEN VERNIER IS UNMESHED
ELEVATION 'B'-END RESPONSE SHAFT

53.123

Figure 8-4.—5"/38 mount train response adjustment (schematic).

1. With the mount in manual, train the mount in the direction of the error to remove the lost motion and record the dial reading. Loosen the locking clamp on the response coupling.

2. Disengage the response coupling and turn the movable section by hand so as to make the dial move the amount of error, and in the opposite direction from the error which exists between the mount and director. In other words, make the train dial reading equal director train dial reading when both are on target and in manual.

3. Move the center section of the coupling until its teeth will engage both the other sections without further disturbing the movable section. Remesh the coupling at this point and tighten the locking clamp.

4. Recheck according to the previously described procedure, and continue to make adjustments until the error is within the allowable tolerance.

5. Tram your mount in train and record the reading in the smooth logs. Make sure parallax is in manual and on zero while tramming.

For example of what you have just covered let's say that director train read 090° when on target. Mount train read 090° 15'. The mount train dial was adjusted to read 090° when on target with the director, both elements being in manual, target at infinity, parallax in manual and on zero.

In the above case the mount was used for marking station since it is easier for the director to train onto the target than it is for the mount using the borescope. However, the end result will be the same regardless of which was used.

Now for a final check. With no ballistics or corrections involved, and with parallax in manual and on zero, you should be able to train the director on target and, with the mount in automatic control, look through the borescope and be on target with the director.

NOTE: Unless elevation is known to be in good alignment, put mount in AUTO in train only, and have pointer bring gun on target in elevation in LOCAL.

Interalignment.—After the 5-inch guns have been aligned in train with the Mk 37 director, the Mk 56 director will be aligned with the Mk 37 director. As a Gunner's Mate you will not normally be called upon during this operation.

After aligning the two directors, the Mk 56 GFCS will be checked for alignment with the 5-inch mounts. Since both the Mk 56 and the 5-inch mounts have previously been aligned to the Mk 37 director, no misalignment should exist; this phase is only a check.

The configuration of the 5"/54 gun mount makes it dangerous to attempt use of the boresight during power operation. For this reason, a different method of battery alignment is used.

When preparing for battery alignment, mount personnel shall remove the covers to all accesses required for boresighting. All power motors are started and allowed to warm up. A target accessible to both mount and director at mean battle range is selected, and the point of target that is to be used is decided on.

NOTE: Ensure that boresight operator and director are in agreement on the exact point of the target.

All operational and parallax checks are conducted, parallax unit dials are set on zero, and mount and director are trained into approximate alignment with the target.

When mount and director are in approximate target area, the mount is placed in manual power and the borescope is installed. Personnel are stationed at train and elevation handcranks, one local control station, boresight, controlling director, and one recorder.

Communication between the boresight operator and the manned stations is established. The local control operator coaches the train handcrank operator until the target is located in the borescope. At this point, the boresight operator begins coaching the handcrank operator and informs the director that he is ready to begin boresighting.

When the ready signal is received, both mount and director are trained toward the target. As the vertical crosshair of the borescope approaches the point of target, the boresight operator calls STANDBY and the director maintains a very close alignment with the target.

When the boresight and director vertical crosshairs are on the target at the same instant, usually decided by the boresight operator calling MARK whenever he is on target, the director and mount dials are read and recorded. Several recordings are taken while approaching the target from the same direction; these readings are added and then divided by the number of readings taken. The result is the average reading.

ALIGNING THE 5''/54 (RF) MOUNTS TO THE 68 DIRECTOR.—After average director and mount readings from one direction are established, the target is approached from the opposite direction. Several readings are taken from this direction. These readings are calculated the same as for the other sets.

The two average mount readings are added and then divided by 2. This establishes a mean reading and corrects for lost motion. The mean director reading is found in the same manner. Next, the mean mount reading is subtracted from the mean director reading, and the result is the error. If the error is less than 2 minutes, no correction is needed. However, if an error of more than 2 minutes exists, the dials must be corrected before continuing with battery alignment.

To prevent upsetting the train limit-stop in relation to true mount position, the dials are adjusted inside the receiver-regulator. Two vernier couplings, shown in OP 2456, Vol. 1, figure 4-21, as B and C, are installed in the train response gearing. Coupling C is used to correct the dial positions; if the dial reads less than the director reading, coupling C is adjusted to increase the mount dial reading. If the dial reading is more than the director reading, coupling C is adjusted to decrease the dial reading.

Movement of coupling C upsets the alignment between dials and synchro receivers, and coupling B is used to restore this alignment. This is accomplished by transmitting a certain value of train gun order to the mount and then, with the mount in automatic control, adjusting coupling B until the dials read the same as the gun order value transmitted. The procedures for adjusting the gun dials and synchros are listed in OP 2456, chapter 4, paragraph 4-6.

ALIGNING THE 3''/50 MOUNTS TO THE MK 37 DIRECTOR.—This procedure is similar to that for aligning the 5''/38 mounts to the Mk 37 director. After the alignment is satisfactory, an alignment check between the 3-inch mounts and the Mk 56 director will be conducted to ensure that the mounts are aligned equally well to the Mk 56 director.

Again, this procedure is best conducted with the ship tied up, and using a target at infinite range with a low angle of elevation.

The procedure for conducting train alignment is as follows:

1. Place the mount control selector switch in Mk 37 Control Position. Check to see that parallax is driven to zero by the zeroing transformer. If it is not, remove the train receiver regulator cover and manually set parallax on zero. Make sure that it stays on zero throughout this alignment. Then, after alignment is completed, correct the action of the parallax system so that the dials are always driven to zero when control is shifted to either the Mk 37 control or Mk 63 control.
2. Install a borescope in the gun, using the left gun of a twin mount.
3. Balance the mount amplifiers.
4. At the director, lock crosslevel on zero.
5. Establish communications between the mount and director.
6. Train the director and mount on target. Shift to manual drive.
7. Mount will "mark" to the director as the borescope crosswire is on target in train. The director pointer trains manually until the pointer's crosswire is on at the mark. When it is on at the mark, record the mount and director train dial readings, and repeat the "mark on" process several times to obtain an average reading. The difference between the mount and director train dials is the alignment error. The ideal alignment is to have both the mount and director on target at infinity, in manual, with the same train values. The alignment tolerance is plus or minus 2 minutes.

Procedure for Correcting Alignment Errors.—Locate the train response adjustment in the train indicator regulator (fig. 8-5) and then:

1. With the mount in manual drive, loosen the response adjustment and turn so as to correct the train dial reading for the alignment error. Tighten the adjustment and recheck on target with the Mk 37 director.

An example of the above: When on target at the mark, in manual, the director train reading was 090°, and the mount train dial reading was 090° 30'. Break the response adjustment, in manual drive, and decrease the mount train reading 30' (from 090° 30' to 090°) so that when trained on the target at infinity, in manual, the director train and mount train are equal.

2. Now tram your mount in train and record your reading. Make sure that your parallax is on zero while tramming.

ALIGNING THE MK 63 DIRECTOR TO THE 3"/50 MOUNT.—Since the 3-inch mounts have been previously aligned to the Mk 37 director, using the mount response adjustments, you can see that no further adjustment of the mount can be made for misalignment between it and the Mk 63 director. Instead, the Mk 63 director will be adjusted to the mount by slipping the gun train order synchro transmitters at the director.

This alignment generally follows the procedures outlined for the previous alignment phase. The following steps are best conducted with the ship tied up.

1. Install a borescope in the local 3-inch mount (mount nearest the Mk 63 director).
2. Install the Mk 63 director alignment telescope.
3. Balance the amplifiers in the mount's train and elevation power drives.
4. Place parallax manually on zero at the mount, and ensure that it will remain on zero during the alignment.
5. Select a target near the horizon at a range and bearing of zero parallax.
6. Train the mount and director on target. Shift the mount to automatic with the Mk 63 director in control.
7. Now, with the director alignment telescope steady on target, note whether the mount borescope crosswire is on target. The tolerance here is plus or minus 1 mil. Estimate the error in alignment by means of the center section of the borescope crosswire, which is 1 mil across.
8. The man at the director, normally a Fire Control Technician, will locate the gun train order transmitters in the director stand.
9. The transmitter stator will be loosened and slipped until the borescope is on target with the mount in automatic. The stator is then locked in place and the electrical zero relationship between the coarse and fine transmitters is checked.
10. Recheck your work by sighting on target.

Alignment in Elevation (Afloat)

The purpose of elevation alignment afloat is the same as that in drydock: to adjust the battery so that at any angle of train or elevation the gun bore axis and the line of sight of the director will all be elevated by exactly the same angle above the reference plane—provided that no vertical parallax or ballistic corrections are introduced, and provided that the dials are matched.

As you remember, the roller path compensator was initially set to correct for the relative tilts between the guns and directors in drydock. The purpose of the alignment phase we are about to describe is to check the correctness of that setting now that the ship is afloat.

You will obtain the information required for the elevation alignment by conducting a horizon check.

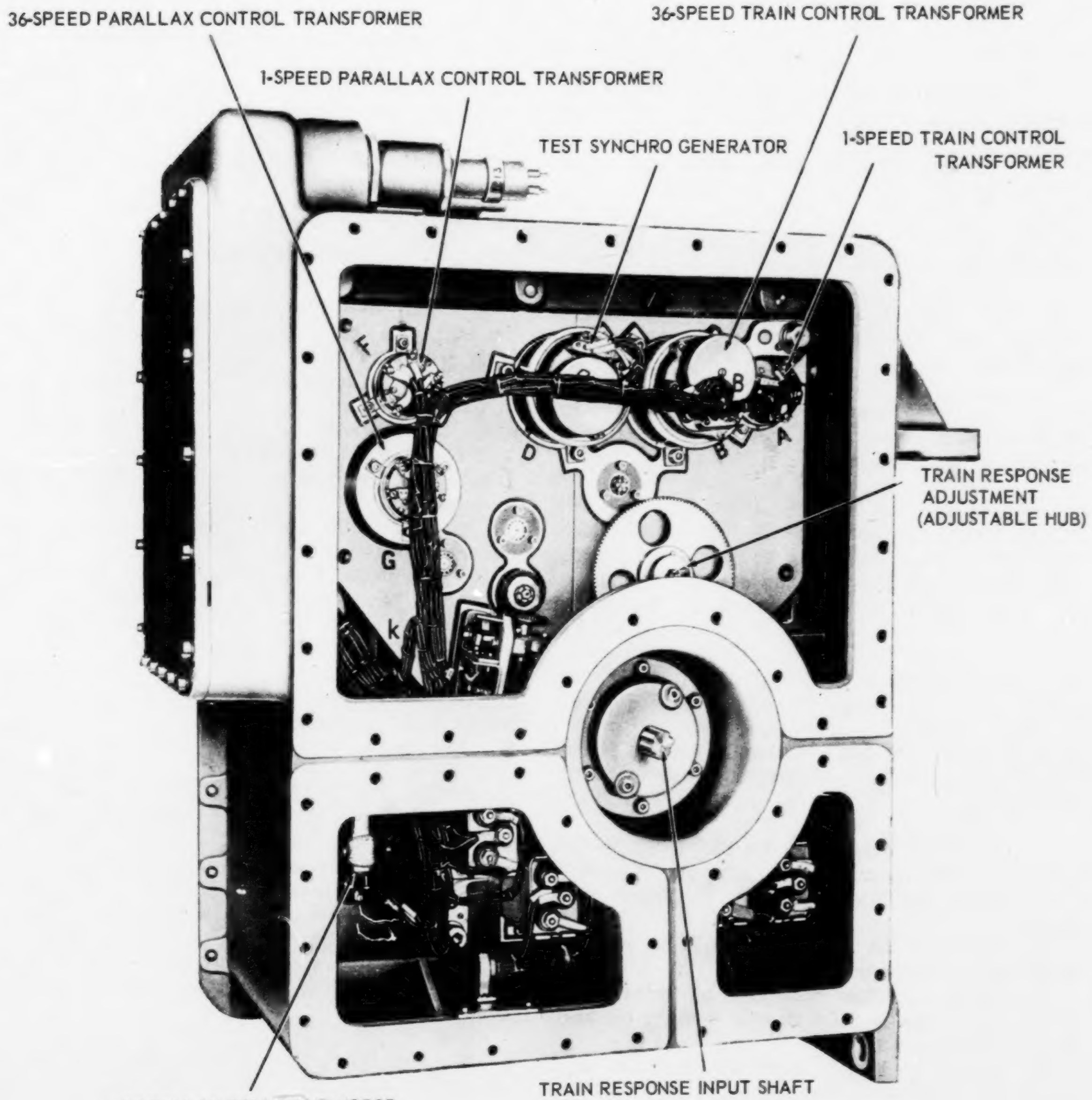
PROCEDURES FOR CONDUCTING THE HORIZON CHECK WHILE ALIGNING THE 5-INCH GUNS TO THE MK 37 DIRECTOR.—The horizon check is conducted by comparing the dial readings of the director and mount as they are aimed at a series of points around the horizon. The ship should be underway, on a steady course, with the ship's speed between 5 and 10 knots. A clear, calm day with a well defined horizon is necessary.

1. Man the following stations: the Mk 37 director, and the 5"/38 mount pointer and trainer, telescopes and borescope. Station a recorder in plot.

2. Install the borescope in the gun.

3. Set parallax manually on zero at the mount.

4. All stations man the JP phones.


36-SPEED PARALLAX CONTROL TRANSFORMER
36-SPEED TRAIN CONTROL TRANSFORMER
1-SPEED PARALLAX CONTROL TRANSFORMER
TEST SYNCHRO GENERATOR
1-SPEED TRAIN CONTROL TRANSFORMER
F
D
B
B
A
G
k
TRAIN RESPONSE ADJUSTMENT (ADJUSTABLE HUB)
TRAIN RESPONSE INPUT SHAFT
PARALLAX FOLLOW-UP MOTOR

53.124
Figure 8-5. — 3"/50 twin mount train response adjustment.

5. Director and mount will train out on the same bearing and shift to manual drive. The pointer at the mount will select a value of elevation at which the borescope horizontal crosswire will move across the horizon as the ship rolls. The man at the borescope gives a clear sharp "mark" as the crosswire meets the horizon. Always mark on the downroll. Do not change the mount elevation after once selecting a point, unless the director is told to disregard the previous marks.

6. The director pointer elevates until his horizontal crosswire is on the horizon at the same instant as the "mark".

7. When the director is "on at the mark," the recorder in plot records the mount and director elevation readings, and the bearings at which they were obtained, as received over the JP telephones.

8. This procedure is repeated throughout a full arc of mount train, obtaining readings for every 15° of bearing.

PROCEDURES FOR PLOTTING THE HORIZON CHECK DATA.—The following material will be required: worksheet, horizon check data graph paper, and polar coordinate paper.

1. On your worksheet subtract all mount elevation readings from the director elevation readings taken at the same bearings. If the mount reading is higher than the director reading, the sign of the difference is positive (+). If the mount reading is lower than the director reading, the sign of the difference is negative(−). The differences obtained in this step are called the "inclination difference values."

2. Plot the inclination difference values on graph paper versus the bearing at which they were obtained. (See figure 8-6). The bearing is the abscissa of the graph and the inclination difference values are the ordinates of the graph. Fill in a smooth curve by connecting as many of the inclination difference plots as follow a predictable path—those that do not create a zigzag erratic curve. The curve should appear as either a sine curve or a straight line parallel to the zero axis of the graph paper. If the plot is a sine curve it will be a single-cycle curve, having but one maximum and one minimum. If the curve does not describe a relatively smooth path (fig. 8-6), the information is probably erroneous and the horizon check should be repeated.

ANALYSIS OF THE HORIZON CURVE.—The horizon check curve will establish the accuracy of the elevation alignment of the mount, and the accuracy of the mount roller path compensator setting.

Following are some facts to consider in making your analysis:

1. A straight line parallel to the zero axis of the graph indicates that the mount roller path is parallel to the director roller path. (The compensators are set correctly.)

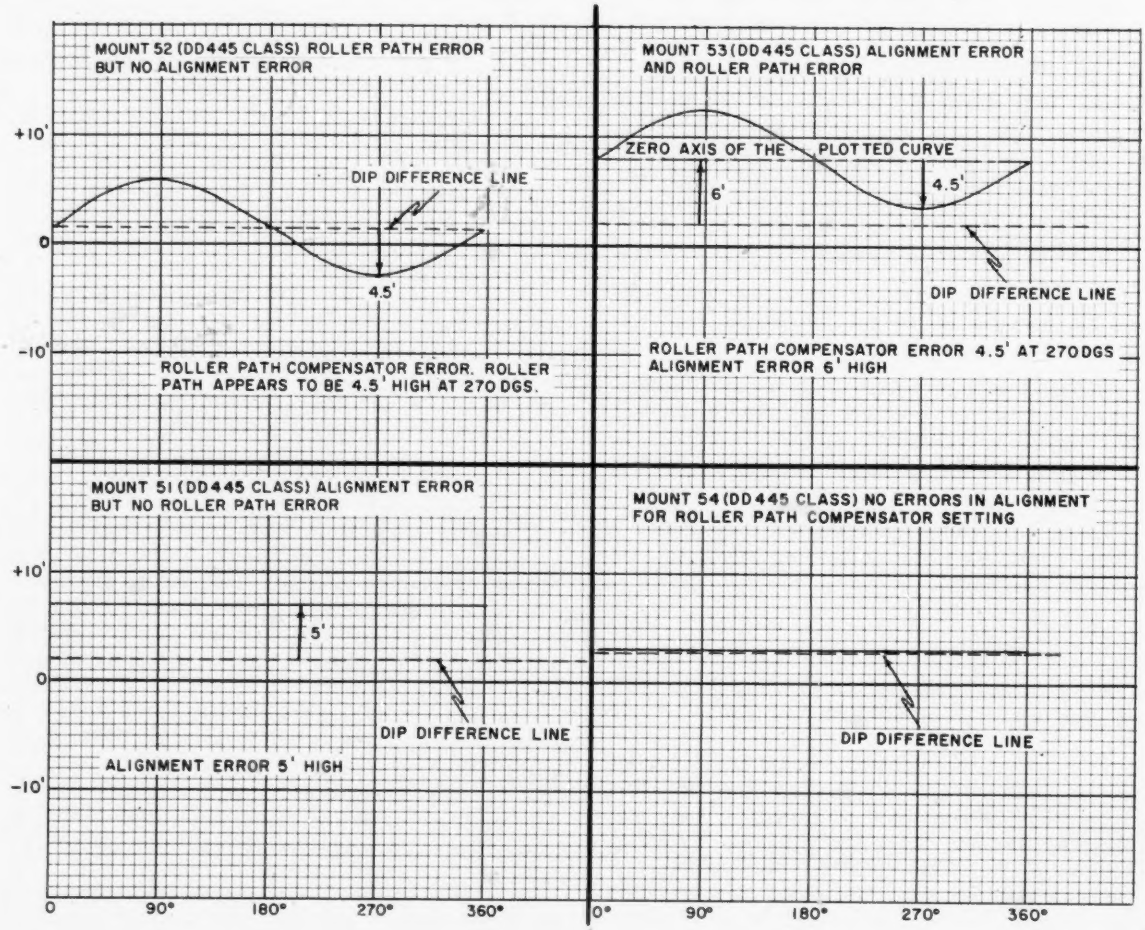
2. A sine curve indicates that the roller path of the mount is not parallel to the director roller path. (The compensators are not set correctly.)

3. There should always be a difference between the mount and director elevation readings due to the difference in height of these elements aboard ship. The director, being higher, must always depress further to sight on the horizon than the mount. This angle of depression onto the horizon is called "dip angle." The difference between dip angle of the director and dip angle of the mount is called "dip difference." (Fig. 8-7). When the mount and director are properly aligned in elevation, the zero axis of the horizon check curve should be above the zero axis of the graph by the amount of dip difference. If the zero axis of the horizon check curve falls at any other point on the graph, an elevation alignment error exists. This error is positive (high) when the zero axis of the curve is above the value of the dip difference, and negative (low) when below the value of dip difference.

4. See table 8-2 for the method of computing dip differences. Draw a straight line through this value on the graph, and note the position of the zero axis of the curve relative to this line. As you can readily see, the magnitude of the difference between the axis of the curve and the dip difference line indicates the elevation alignment error.

5. If the horizon data is plotted as a sine curve, instead of a straight line parallel to the axis of the graph, then the roller path is not parallel to the director. The low point of this sine curve is the high point of the roller path, and the bearing of the high point is the bearing at which the low point of the curve occurred. If the roller path is not parallel, as in this case, then new compensator settings must be computed.

NOTE: To compute dip angle and dip difference, consult ship's plans to obtain the height of the elements above the waterline. Dip angle



53.125

Figure 8-6.—Samples of a sine curve.

is required for both director and mounts. Enter table 8-2 at this height to obtain the dip angle to horizon. Subtract the dip angle of the mount from the dip angle of reference Director Mk 37. The difference is dip difference. It should be constant at all bearings.

CORRECTING ALIGNMENT ERRORS AND COMPUTING ROLLER PATH SETTINGS.—To correct elevation alignment errors:

1. Locate the mount's elevation response coupling.

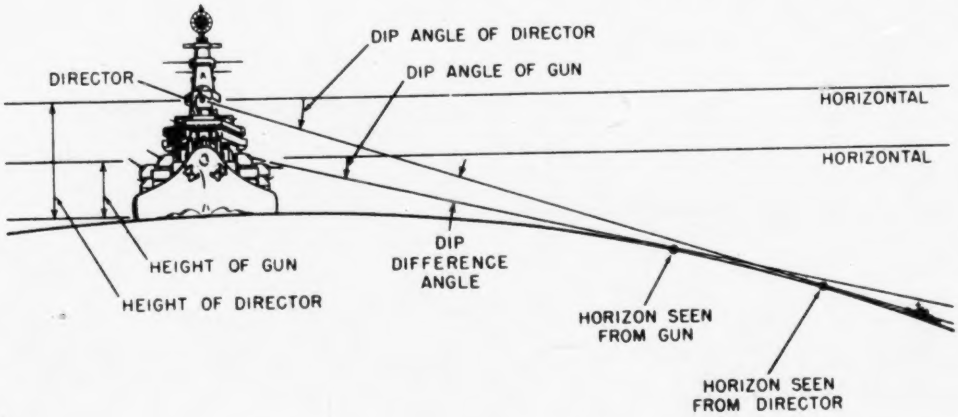
2. Note the elevation dial reading on the mount's indicator regulator.

3. While in manual drive, loosen the response coupling and turn until the elevation dials read the correct value as established by the analysis of the horizon check curve.

4. Tighten the response coupling after setting the dials, and recheck on several bearings to refine the adjustment.

To compute new roller path compensator settings:

1. On the polar coordinate paper, lay off a vector to scale, representing the roller path



92.48

Figure 8-7.—Dip angle and dip difference.

compensator setting that existed during the horizon check (fig. 8-8).

2. Lay off a second vector to scale, representing the bearing and magnitude of the roller path high point as established on the horizon check curve. Remember that this high point of the roller path is the low point of the sine curve.

3. Parallel the vector representing the high point of the roller path over until its tail lies at the head of the vector representing the old compensator setting.

4. Draw in a resultant vector from the center of the polar coordinate paper to the head of the vector just paralleled in.

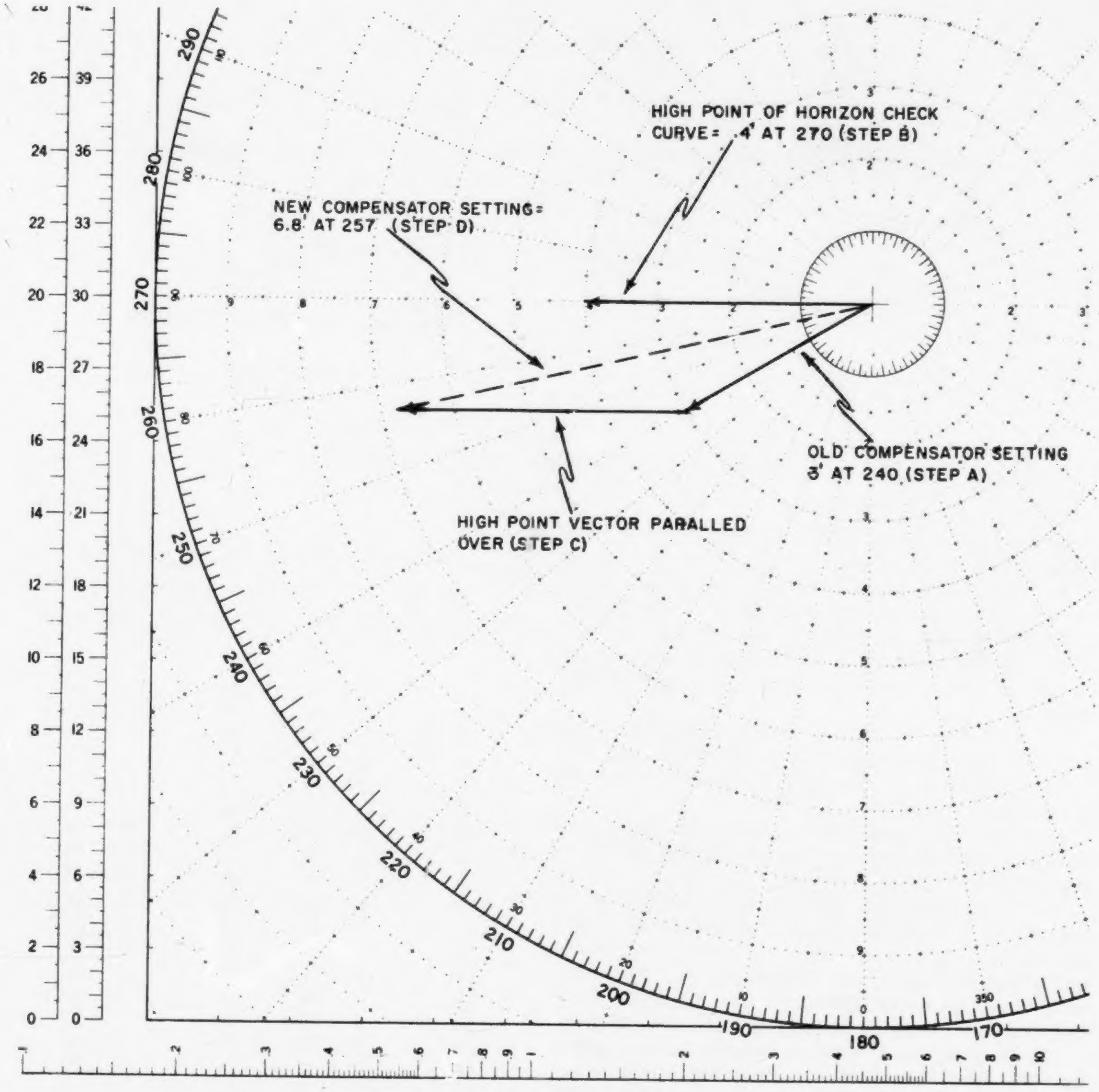
5. The resultant vector from the center of the polar coordinate paper to the head of the paralleled high-point vector is the new compensator setting. The length of the resultant vector is the magnitude of the required setting at the bearing at which this vector lies.

Let's stop and think a minute before going into the details of setting the roller path compensator. The roller path compensator was set during the drydock alignment. After this initial setting has been made, it is poor practice to attempt to reset the corrector every time a small error in roller path alignment is defected.

A small observed error may be the result of incorrect readings, or of incorrectly analyzing roller path data, etc. For these and other reasons, it is better policy to leave them as they are, unless a large error is found, until several sets of readings taken over a period

Table 8-2.—Dip of the Sea Horizon

Height, ft	Dip Angle		Height, ft	Dip Angle	
	'	"		'	"
1	0	59	26	5	00
2	1	23	27	5	06
3	1	42	28	5	11
4	1	58	29	5	17
5	2	11	30	5	22
6	2	24	31	5	27
7	2	36	32	5	33
8	2	46	33	5	38
9	2	56	34	5	43
10	3	06	35	5	48
11	3	15	36	5	53
12	3	24	37	5	58
13	3	32	38	6	02
14	3	40	39	6	07
15	3	48	40	6	12
16	3	55	45	6	36
17	4	02	50	6	56
18	4	09	55	7	16
19	4	16	60	7	35
20	4	23	65	7	54
21	4	29	70	8	12
22	4	36	75	8	29
23	4	42	80	8	46
24	4	48	85	9	02
25	4	54	90	9	18
			95	9	33
			100	9	48

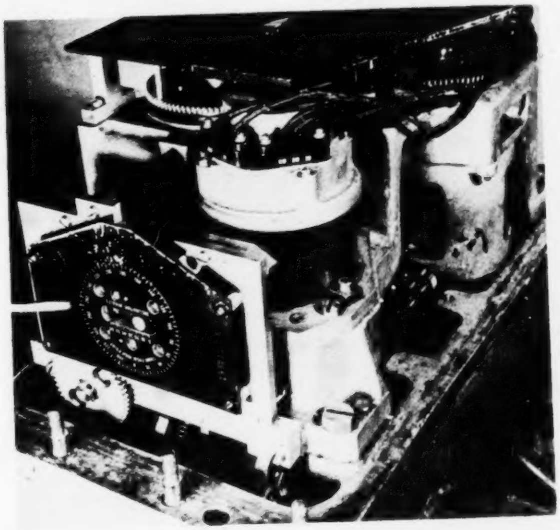


53.127
Figure 8-8. — Computing new roller path compensator settings.

of time show definitely that a change in setting is required.

Setting the Two-Scale Compensators.—To assist you, in case a new setting is required, the procedure for the common 2-scale compensator as used on the 5''/38 twin mount is shown (fig. 8-9).

1. Remove the cover on the elevation indicator regulator to expose the roller-path compensator.



53.128

Figure 8-9. — 5"/38 twin mount roller path compensator.

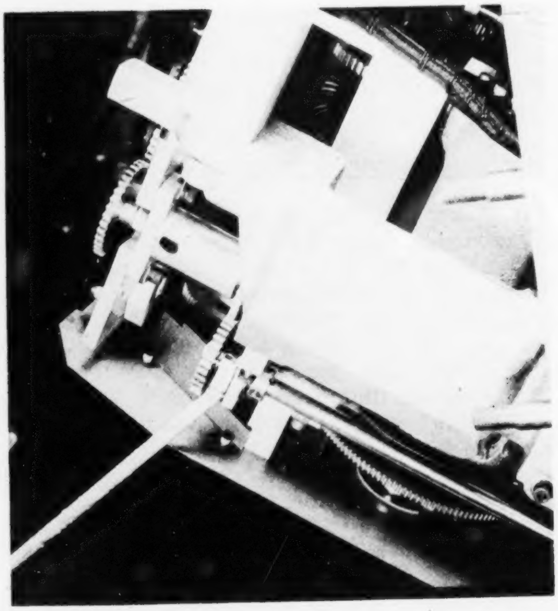
2. Loosen the four inset screws on the face plate, and set the index pin to the new compensator setting. (This is the amount of inclination at the high point of the roller path.) Tighten the inset screws.

3. Loosen clamp A-6, on the horizontal shaft adjacent to the left-hand edge of the dial mask (fig. 8-10). Set the compensator bearing scale to read 0° bearing while the mount is trained to the high point of its roller path. Tighten A-6.

The mount can now be trammed in elevation and the reading recorded. Always tram the mount in elevation while trained 90° from the high point of the roller path.

INTERALIGNMENT.—At this point the Fire Control Technicians will align the Mk 56 director to the Mk 37 director in elevation. After this is accomplished, the Mk 56 director can be checked in elevation with the 5"/38 mounts. Since both the 5-inch mounts and the Mk 56 director have previously been aligned to the Mk 37 director, there should be no error. If, however, an error should exist, the previous alignments should be rechecked.

ALIGNING THE 3"/50 MOUNTS TO THE MK 37 DIRECTOR.—In conducting the following procedure, data will be obtained by a horizon check, as previously described. The alignment procedure is as follows.



53.129

Figure 8-10. — 5"/38 twin mount roller path compensator train adjustment A-6.

1. Place the mount control selector lever switch in either Mk 37 or Mk 63 control to check that parallax is driven to zero. The mount amplifiers should be balanced.
2. Install the borescope, using the left gun of a twin mount.
3. Train the director and mount on the same bearing, and shift to manual drive. The mount will "mark" to the director as the borescope crosswire is on the horizon. The director pointer elevates until the pointer's crosswire is on the "mark."
4. When on at the "mark," record mount and director elevation, and the bearing at which the readings were obtained. Repeat this process throughout the complete arc of mount train.

The procedure for plotting horizon check data and analyzing the results is identical with that described for 5"/38 mounts. Remember to consider dip difference in the analysis as in the previous steps.

The following procedure is to be used for correcting elevation alignment and roller path errors. For purposes of this explanation we have chosen the twin 3"/50 mount. For information on correcting errors in 3"/50 mounts, refer to OP 1698 3" Mounts Mk 34 Mods 0 and 1.

Elevation alignment errors

1. Locate the elevation response adjustment on the mount (fig. 8-11).
2. Note the elevation dial reading on the mount while in manual drive.
3. Loosen the response adjustment and turn until the mount dial reading is corrected for dial error. For example: Mount dial reads 2010 minutes; dial error from axis of curve is 10 minutes low or negative; adjust for dial reading of 2020 minutes.
4. Tighten response adjustment and recheck with the Mk 37 director.

Roller path compensator setting

CAUTION: As for the 5"/38 mounts, you should be absolutely certain that a new setting of the compensators is needed. This is determined by taking several sets of readings over a period of time.

1. Determine the setting that existed on the mount during the horizon check. Compute the new setting, using the procedure outlined in the section on alignment of 5"/38 mounts to the Mk 37 director.
2. Locate the mount compensator (fig. 8-11). It has 3 scales.
3. Loosen the two large screws, one above and one below scale A, and turn scale B to read zero at the bearing of the high point.
4. Loosen the four screws in the recesses, two above and two below the scale A. Move the index pin of scale A to read the amount of tilt of the roller path at its high point.
5. Check to make sure that the C scale reads mount train. The roller path compensator scales register the following: The A scale always reads amount of inclination; the B scale reads the amount of gun train from the high point; and the C scale, if the installation is equipped with one, reads straight mount train. (Fig. 8-12.) The mount can now be trammed in elevation and the reading recorded. Remember to always tram your mount in elevation with the mount 90 degrees from the roller path high point.

INTERALIGNMENT.—The Mk 56 director can now be aligned to the 3"/50 mounts. As before, this phase should constitute a check only, as the 3"/50 and the Mk 56 director have already been aligned to a common director, the Mk 37.

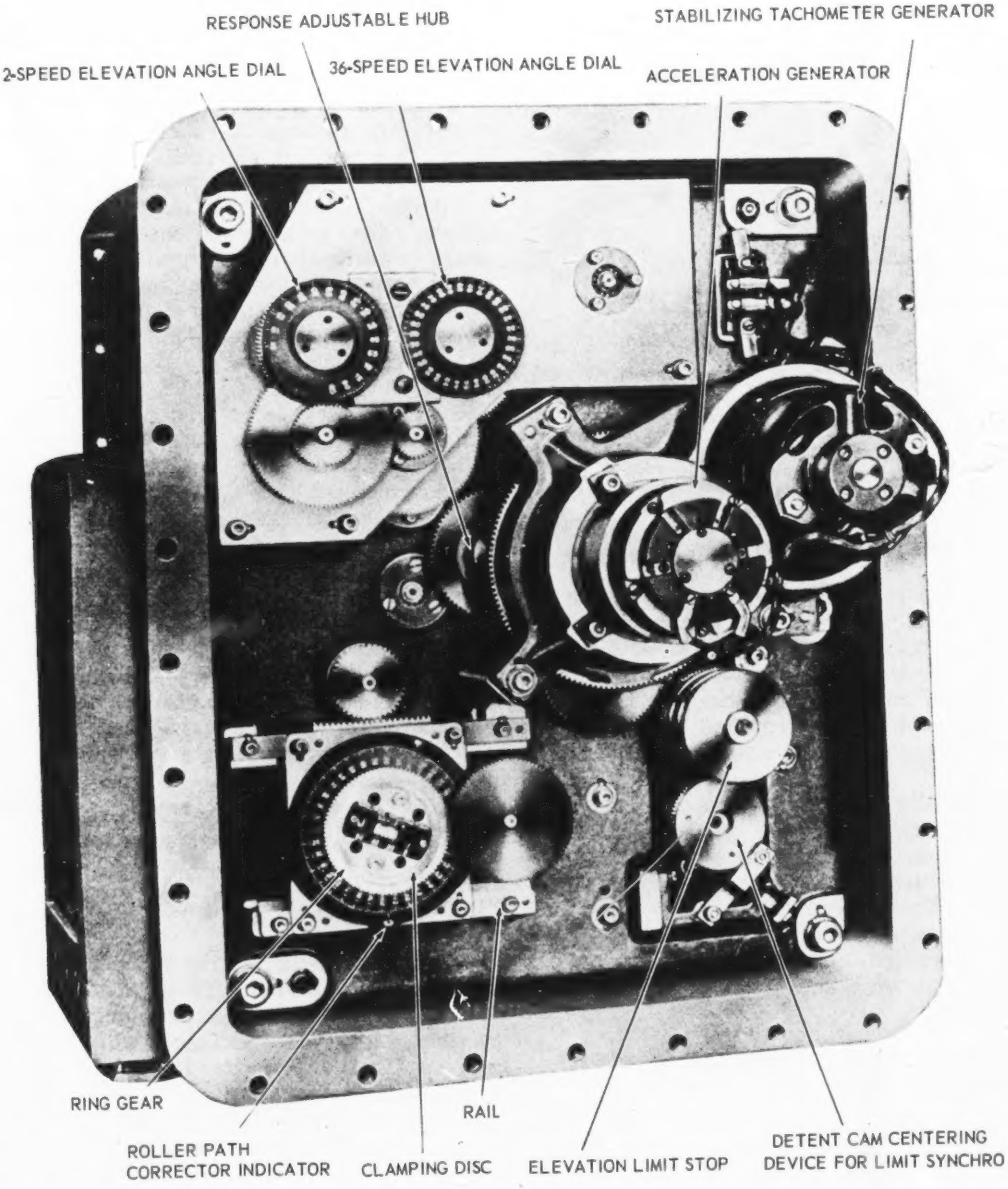
ALIGNING THE MK 63 DIRECTOR TO THE 3"/50 MOUNTS.—This procedure is similar to those specified earlier in the alignment phases. Since the 3"/50 mounts have been aligned in elevation to the Mk 37 director, no adjustment can be made to the 3-inch mounts for misalignment to the Mk 63 director. Instead of the mount being aligned to the director, the director must be adjusted to the mount by slipping the gun elevation order synchro transmitters.

1. Energize the Mk 63 GFCS and the 3"/50 mount. Balance the mount amplifiers.
2. Install the borescope in the left gun.
3. Select a target near the horizon, at a range and bearing of zero parallax. Ensure that parallax is on zero at the mount.
4. With the mount in automatic, train the director and mount on target.
5. Note the difference in elevation at the mount borescope while on target. A 1-mil tolerance in elevation is permitted.
6. Correction for alignment error may be made by slipping the gun elevation order synchro transmitters at the director.

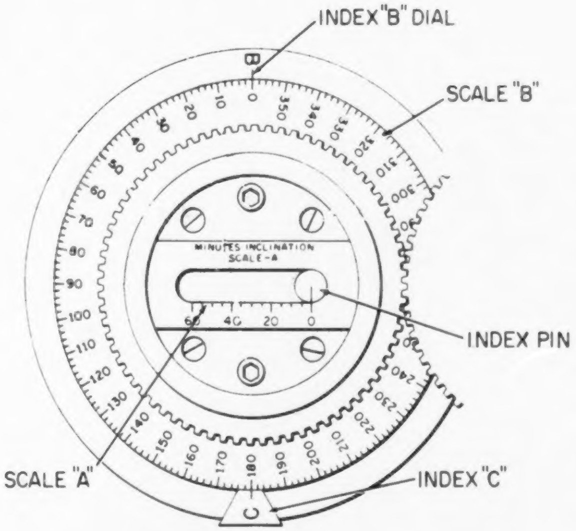
FIRING STOP MECHANISMS

It's hard to overemphasize the importance of checking the firing stop mechanisms after making the original alignment, or after doing any work or repair on the mounts or turrets that would disturb the firing stop mechanism, or in the course of routine checkups. Every casualty from the ships firing into their own superstructures testifies to the seriousness of ANY misalignment of the firing stop mechanisms. Equally important: In EVERY case these casualties could have been prevented. They resulted from negligence on the part of the ship's personnel; or cams were cut improperly and in some cases misaligned; or the firing stop mechanisms were inoperative through lack of preventive maintenance.

As you remember, firing stop mechanisms are designed to interrupt electrical firing circuits and firing mechanism linkages whenever guns are trained or elevated to a position


RESPONSE ADJUSTABLE HUB
STABILIZING TACHOMETER GENERATOR
2-SPEED ELEVATION ANGLE DIAL
36-SPEED ELEVATION ANGLE DIAL
ACCELERATION GENERATOR
RING GEAR
RAIL
ROLLER PATH CORRECTOR INDICATOR
CLAMPING DISC
ELEVATION LIMIT STOP
DETENT CAM CENTERING DEVICE FOR LIMIT SYNCHRO

53.130
Figure 8-11. — 3"/50 twin mount elevation response adjustment.



110.83
Figure 8-12.— Three-scale roller path compensator as used in the 3"/50 twin mount.

where firing the guns would endanger personnel or damage the ship. They should not be confused with the depression stop cams that are used occasionally to limit the movement of some guns to a safe zone of fire, or with train or elevation limit stops. Firing stop mechanisms do NOT interfere with the free movement of the gun.

Naval Ordnance Systems Command has issued definite instructions for the guidance of the personnel responsible for plotting, cutting, installing, and checking firing cutout cams and mechanisms. These regulations apply strictly in all cases. In addition, special instructions govern particular gun installations, for example, the firing limits of some mods of 3" and 5" R.F. gun mounts.

NAVORDSYSCOM REGULATIONS FOR FIRING CUTOUT CAMS

Obviously, firing cutout mechanisms must prevent firing into permanent parts of the ship's structure. But what about movable accessories, deck gear, and rigging?

NAVORDSYSCOM regulations specify that when you lay out firing cutout cams, you must assume that removable parts of the ship's structure—such as stanchions, handrails, lifelines, davits—and such equipment as boats, chests, lockers, and hatches, have been removed so as not to obstruct the line of fire. NAVORDSYSCOM similarly does not approve of cutting cams to provide protection for forestays, halyards, radio antennas, and similar top hamper. The idea is that in peacetime, practice firing must be arranged to avoid these obstructions; while in combat, damage to them is considered a hazard that must be accepted.

Of course, some movable parts of the ship's structure, including such major items as guns, mounts, radar antennae, booms, and cranes, often cannot be turned where they will be out of the line of fire. Firing cutout cams must be cut so as to prevent fire at such parts of the ship. The same applies where personnel, such as gun crews, are unavoidably exposed to the line of fire; the cam must be cut so as to protect them.

Firing cutout cams designed in accordance with these instructions will naturally not restrict firing to prevent injury to personnel located where they are subject to muzzle blast effect, nor can they prevent damage to gear that has not been moved clear of the line of fire.

When plotting cams for firing cutout mechanisms, a safety clearance must be maintained in train and elevation between the extended axis of the gun bore and the fixed structure of the ship. The amount of safety clearance will vary from one type of gun to another because of differences in firing mechanism lag, and rate of train and elevation, etc. In all cases the proper amount of safety clearance may be found in the latest editions of NAVORDSYSCOM publications, and should be observed when plotting the cams.

FIRING CUTOUTS FOR GUNS 6 INCHES AND LARGER

Most main battery guns 6 inches and larger have separate firing cutout mechanisms for train and elevation. In train, a plunger and cutout switch are located on and move with the carriage. Cam surfaces on the stand, near the roller path at relative bearings coincident with the danger area, operate the cutout switch. The elevation cutout is a flat cam and plunger mechanism mounted on the deck lug of the gun. Movement of the gun in elevation rotates the cam.

On larger caliber bag type guns, only the electrical firing circuit is interrupted by cutout cams. The percussion firing circuit is NOT affected. However, the cutout mechanism energizes warning lights in the mount or turret to indicate when the gun is in a danger zone and should not be fired by percussion.

The proper settings for these firing cutout mechanisms are outlined in the applicable OPs. Usually the OPs will list the settings for the individual turrets on ships of a class. After the cams are installed they must be checked by the methods to be outlined later.

TYPES OF CUTOUT CAMS

Figure 8-13 shows two types of cutout cams and firing stop plungers. Cam A is typical for use with a 5"/38 gun mount; while cam B is typical for use with 5"/54 Mk 1 through 9 gun mounts. Cam A is a disc-shaped profile cam which has an irregular camming surface machined into its face (flat side). Cam B is a cylindrical barrel cam whose camming surfaces are grooved around the outside of the barrel cam. Both types of firing cutout cams are illustrated and explained in GMG 3/2 NP 10185-A.

Profile Cam Mechanism

In the remainder of this chapter we shall take up firing cutout mechanisms in which a disc-shaped profile cam controls the firing mechanisms when the gun is in or near a danger zone of fire in either train or elevation. Such mechanisms are used on 40-mm, 3"/50, 5"/38, and some Mods. of 5"/54, and larger caliber guns, such as the 8-inch rapid-fire. Details of these mechanisms differ slightly from one type of mount to the next, but in principle they are similar and can be considered collectively. You will be responsible, as a Chief Gunner's Mate, for plotting, installing, and checking the functioning of these cams, though you will not actually cut them.

Cam A in figure 8-13, shows a cutaway view of a typical firing stop mechanism plunger and profile cam; this one is from a 5"/54 Single Mount Mk 39. The cam turns as the mount trains at one-to-one speed, while the plunger mechanism moves toward the center of the cam as gun elevation increases. At minimum elevation, the plunger is near the edge of the cam. The high areas of the cam plate correspond to danger zones in which it is unsafe to fire. (You should already be familiar, from earlier courses in this series, with the mechanical linkages that operate the firing cutout mechanism.)

The rise from the cutaway area to the raised portion of the cam is a 30° incline. This permits the plunger cam follower to ride from the low surface of the completed cam to the high surface without binding, excessive wear, or scoring. Cutout occurs when the plunger is two-thirds of the way up the incline. Remember this when laying out the cam. It is necessary to scribe on the cam two additional lines, besides the line representing the danger zone of fire, to represent the top and bottom of the incline.

In tracing the safe fire zone of any mount having more than one gun, a separate cam must be traced for each gun. (An exception is the 40-mm mount where each cam controls the firing mechanism of a pair of guns. A 40-mm quad mount therefore requires two cams—one for each pair of guns.) Thus one gun of a multigun mount may stop firing and the other gun, or guns, continue to fire until their firing cutout switches are actuated by their respective firing cutout cams.

PLOTTING THE CAM ON A 5-INCH OR 40-MM MOUNT

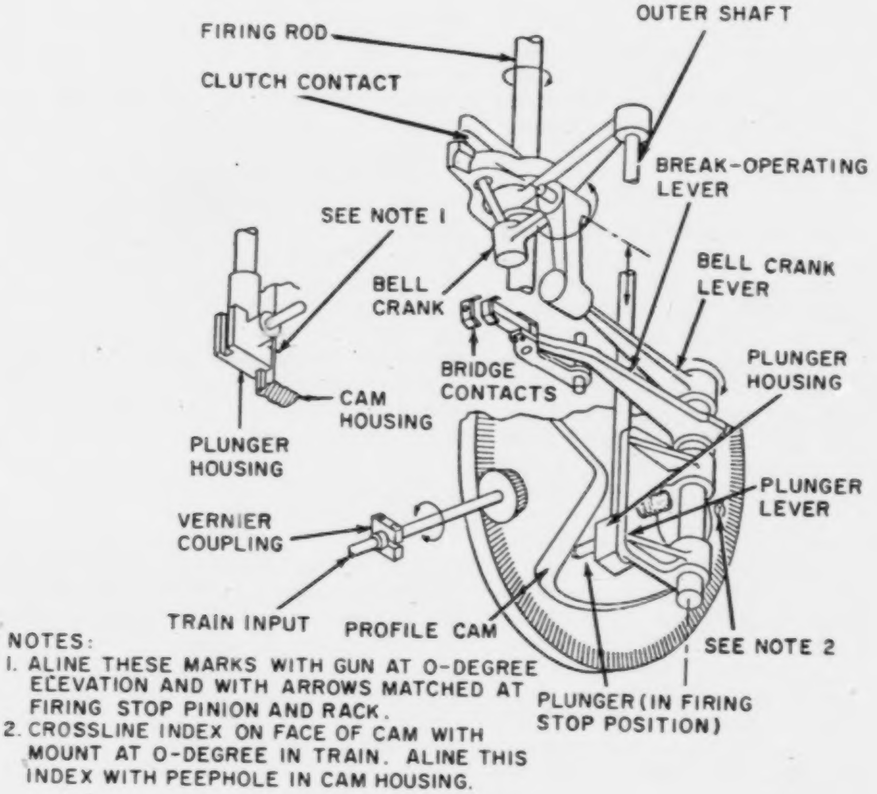
The entire firing stop mechanism, with the exception of the profile cam, is installed on the mount at the time of manufacture. Because the profile of the cam will vary with the location of the gun, the cam must be plotted after the gun is installed aboard ship. The method of plotting the cam depends upon the type of gun. Either of two methods may be used for 40-mm and 5-inch mounts, while 3"/50's, because the cam is inaccessible, require still a third method.

Method No. 1 For 5-Inch And 40-mm Guns

The main steps in this method are to map out the zone of permissible gunfire by means of a boresight in the bore of the gun; then to plot the angles of elevation at the corresponding angles of train on a cam plotting sheet; and last to transfer this plot to the cam blank. One type of sheet (known as No. 8) is used for cams that rotate counterclockwise for right train; No. 9 is used for cams that turn clockwise for right train.

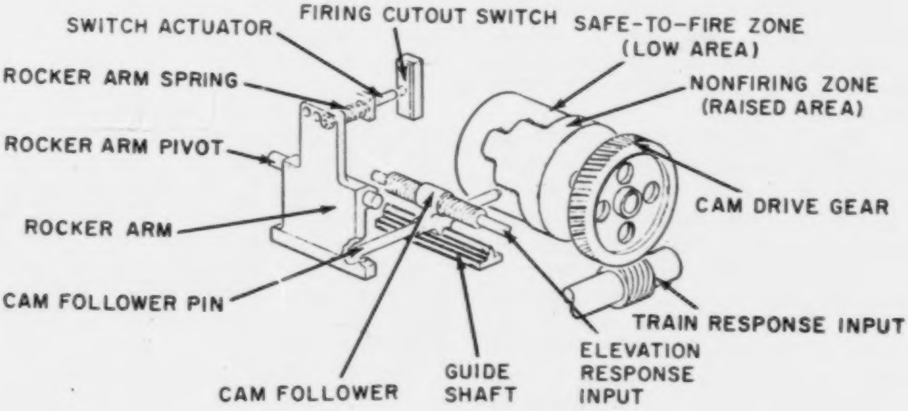
Here is the general procedure:

1. Install and align a boresight in the bore of each gun. Take sights on the whole area of possible train and elevation to locate all obstacles, as required by NAVORDSYSCOM regulations. Take enough readings of elevation and train


FIRING ROD
OUTER SHAFT
CLUTCH CONTACT
BREAK-OPERATING LEVER
SEE NOTE 1
BELL CRANK
BELL CRANK LEVER
BRIDGE CONTACTS
PLUNGER HOUSING
CAM HOUSING
PLUNGER HOUSING
PLUNGER LEVER
VERNIER COUPLING
TRAIN INPUT
PROFILE CAM
SEE NOTE 2
PLUNGER (IN FIRING STOP POSITION)

NOTES:
1. ALINE THESE MARKS WITH GUN AT 0-DEGREE ELEVATION AND WITH ARROWS MATCHED AT FIRING STOP PINION AND RACK.
2. CROSSLINE INDEX ON FACE OF CAM WITH MOUNT AT 0-DEGREE IN TRAIN. ALINE THIS INDEX WITH PEEPHOLE IN CAM HOUSING.

CAM A


SWITCH ACTUATOR
FIRING CUTOUT SWITCH
SAFE-TO-FIRE ZONE (LOW AREA)
ROCKER ARM SPRING
NONFIRING ZONE (RAISED AREA)
ROCKER ARM PIVOT
ROCKER ARM
CAM DRIVE GEAR
CAM FOLLOWER PIN
TRAIN RESPONSE INPUT
ELEVATION RESPONSE INPUT
GUIDE SHAFT
CAM FOLLOWER

CAM B

53.291
Figure 8-13. — Firing cutout mechanism and gearing.

angles to outline accurately the zone of permissible or safe gunfire.

2. Mount the cam blank on the cam gear and dowel it in place. With the mount at 0° train and all shafts to the firing cutout mechanism fully coupled and pinned, insert a machinist's scribe through the peephole in the cam housing and mark the cam blank with a circle and cross (Note No. 2, figure 8-13).

3. Remove the cam blank from the cam gear. With a scribe and straight edge, draw a radial reference line across the face of the cam through the geometrical center of the circle marked in step 2. Draw a second radial line through the center of the cam, but perpendicular to the reference line.

The next step is to transfer the elevation and train readings to the cam blank. For this purpose you use blank cam plotting sheets, which are the same size as the cam blank. These are furnished each outfitting yard. (When ordering blanks, be sure to specify the bore, length in calibers, and mark and mod of the gun, and whether the cam turns clockwise or counterclockwise for right train.)

Figure 8-14 shows a sample cam plotting sheet (reduced in size, of course) marked for a 5"/38 gun. The concentric circles represent gun elevations in 5° units; the table at the bottom of the sheet indicates the radius in inches from the center of the diagram for each 5° elevation. The radiating lines represent mount train angles. The train angle bearing lines are not truly radial because the plunger, as it travels across the cam, follows a line tangent to a circle of 0.814-inch radius struck from the center of the cam. The circle and cross printed on the sheet's edge are so placed that, when lined up with the one you've scribed on the cam blank, the position of the plunger on the cam, when installed, will correspond to the train of the gun.

Now we can go on with the fourth step in laying out the cam:

4. Fasten the plotting sheet on the cam blank so that the center line and cross printed on the sheet coincide with the center line and cross scribed on the cam. Then you plot the outline of the firing zone on the sheet, using the readings taken in step 1. Use the circles and radiating lines on the sheet to give you the coordinates of each point to be plotted. For example, suppose you want to plot a point at 55° elevation and 270° train. The table shows that you plot 55° elevation on the circle 2.280 inches from center. Set a pair of dividers at 2.280 inches; then, basing one leg on the center of the plotting sheet, swing the other until it intersects the 270° bearing line. Mark this point. Continue with the remainder of the readings until all are plotted.

5. You now have a series of points on your plotting sheet. Connect them with a smooth curve. The outline you now have represents the safe and the danger firing zones. But you know that there must be a 30° incline between the two. You must plot lines representing the top and the bottom of this incline. The line you have already plotted may be considered as being about two-thirds up the slope. On a 5"/38 cam, the outer line (representing the top of the slope) is about 0.072 inch from the line you have already plotted; the inner line (base of slope) is about 0.144 inch from the plotted line. With other mounts, you should follow the instructions in the OD to fix the positions of the inner and outer lines. In any case, however, you must ALWAYS measure the distance between the lines of a PERPENDICULAR to a tangent drawn to the plotted line, at each plotted point. Figure 8-15 illustrates the general idea.

6. To transfer the plotted lines to the cam blank, use a center punch.

Method No. 2 For 5-Inch And 40-MM Guns

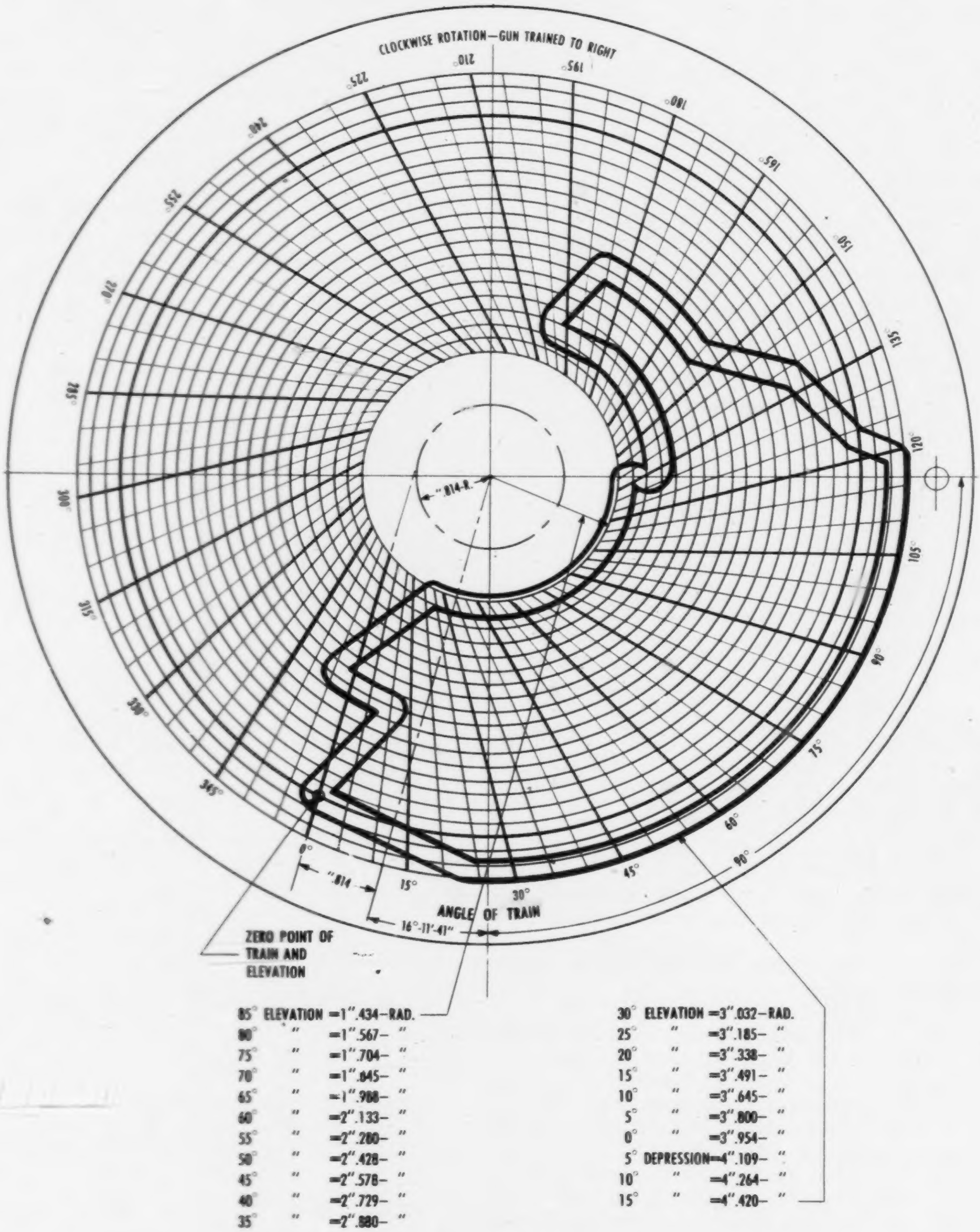
In this method, instead of taking observations, noting down the coordinates, and plotting the profile from them, you use the firing stop mechanism itself to trace out the profile right on the blank cam. Here are the details:

1. With the mount at 0° train, remove the cam housing, secure the cam to its gear, and put it in place. Replace the plunger that normally rides on the cam with a marking pin or scribe of the same diameter, but from 0.10 to 0.20 inches shorter in length.

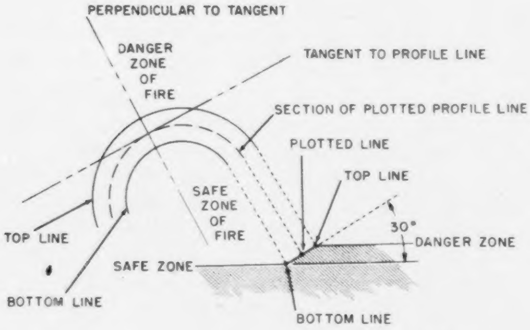
2. Reassemble the cam housing and couple and pin all shafts. Install the gun's boresight.

3. With all connections made, and the mount at 0 train, scribe the circle and cross on the blank cam as was described in method No. 1.

4. Next, with the mount at 0° train, run the gun to the maximum elevation. With the gun at maximum elevation, train the gun through its entire arc of train returning to 0° train.


CLOCKWISE ROTATION—GUN TRAINED TO RIGHT
210°
195°
180°
165°
150°
135°
120°
105°
90°
75°
60°
45°
30°
15°
0°
345°
330°
315°
300°
285°
270°
255°
240°
225°
".814-R.
".814
90°
ANGLE OF TRAIN
16°-11'-41"
ZERO POINT OF TRAIN AND ELEVATION
85° ELEVATION =1".434-RAD.
80° " =1".567- "
75° " =1".704- "
70° " =1".845- "
65° " =1".988- "
60° " =2".133- "
55° " =2".280- "
50° " =2".428- "
45° " =2".578- "
40° " =2".729- "
35° " =2".880- "
30° ELEVATION =3".032-RAD.
25° " =3".185- "
20° " =3".338- "
15° " =3".491- "
10° " =3".645- "
5° " =3".800- "
0° " =3".954- "
5° DEPRESSION=4".109- "
10° " =4".264- "
15° " =4".420- "

53.132
Figure 8-14.—Sample cam plotting sheet (No. 9) for 5"/38 mount.



53.133
Figure 8-15.—Plotting the top and bottom lines on a firing cutout cam.

5. Now depress the gun to maximum depression and again train the gun through its entire arc, returning to 0° train. This establishes exact lines of reference for 0° train and for maximum elevation and depression.

6. Starting at 0° train and maximum depression, train the gun until the line of the bore, using the boresight, intercepts the first part of the nonfiring zone. Beginning at this point and using extreme care with the elevating and training gear, follow the outline of the ship's structure, sighting down the bore as before.

7. The line thus traced on the cam blank by the pointed pin should be considered as being approximately two-thirds of the way up the 30° incline of the cam. Additional lines representing the top and bottom of the incline should then be inscribed on the cam.

In both methods of marking the cam blank, the actual profile line is very likely to take a course too jagged to follow when the cam is machined. You must consider this when laying out the cutting lines. The lines can be materially straightened without much loss of firing area. Of course the firing cutout cam is designed for safety, and safety is the first factor to be considered when deviating from the actual profile line.

Each cam should have an identification stamp. The information on it should include the name of the ship, and the number and location of the gun for which it was made.

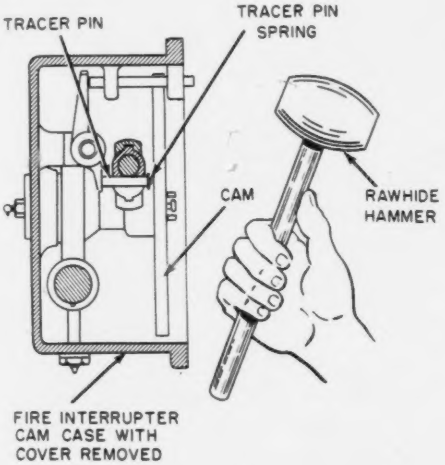
It may not be possible or convenient to use 0° train as the registration point for the circle and cross of the cam. In this case any convenient angle may be used, as long as the value of that angle is inscribed on the legend of the cam. For example, if the gun is on 270° bearing when the circle and cross are inscribed on the cam, the legend on the cam should specify: INSTALL AT 270° TRAIN." Subsequent reinstallation of the cam should be governed by this legend.

PLOTTING THE CAM ON A 3"/50 RAPID-FIRE MOUNT

On the 3"/50 rapid-fire mount the profile side of the cam is toward the inside of the cam case. It is therefore impossible to scribe it directly. Instead, proceed as follows:

1. Remove the cam case cover, the blank cam and the cam follower pin. Insert in the pin's place a cam tracer pin with its point toward the inside face of the cam. Attach the tracer pin spring and secure it under the head of the screw intended for that purpose in the cross feed block. Replace the blank cam and secure it in place. Do not replace the cam case cover, because the switch pushrod must be accesible for this operation.

2. Train and elevate the gun so as to follow the outline of the nonfiring zone of the cam. Trace the zone outline on the cam by tapping the switch push pin lightly with a rawhide mallet between movements of the gun (fig. 8-16). Be sure to allow the minimum safety clearance between the line of fire and the edge of any obstruction.



53.134
Figure 8-16.—Cam layout procedure on the 3"/50.

After plotting a cam by any of the methods above, you turn it over to the yard for machining. When the machine work is completed and the cam is returned to the ship, it must be oriented and installed according to the instructions contained in the ordnance publication on that type of mount. (See OP 0 on this.)

Finally, you must check the accuracy of the cam profiles and the adjustment of the firing stop mechanism. Following is a suggested procedure. (The voltmeter recommended may be replaced by an electric lamp of the correct voltage rating, if desirable.)

1. Make sure that the gun is NOT LOADED.
2. Lay the gun so that it is OUTSIDE of a danger zone.
3. Complete the firing circuit as for local firing.
4. Connect a suitable standard voltmeter between the firing pin and ground, or across the terminal of the firing cutout switch. Do NOT use a vacuum tube voltmeter.
5. The voltmeter will indicate full firing circuit voltage, if the circuit is completed properly (as it should be).
6. Lay the gun so that it is WITHIN a danger zone. The voltmeter should now read zero.
7. Train and elevate the gun in and out of the firing zone at various points. Check to see that the operation of the firing stop switch, as indicated by the voltmeter, occurs at the proper points.
8. If percussion firing is also included in the cutout mechanism, check to see that the percussion firing mechanism cuts out whenever the switch in the firing circuit opens. If a voltage is present in step 6, or during step 7 when the gun is in a danger zone, FIRST check for a defective firing stop switch, a defective or short-circuited plug, or faulty cable insulation. If they check out OK, then you may suspect the firing stop cam layout.

This chapter has presented basic information on firing-stop mechanisms for 40-mm, 3''/50, and 5-inch mounts. For details on disassembly, installation, and reassembly of the components of these mounts that are concerned with firing stop mechanisms, consult the OPs dealing with the mounts. For further details on the procedure for plotting and making the cam plates on 5-inch mounts, see OD 2071 and OD 3486. For information on main-battery firing stop mechanisms, see OD 3222. And, of course, you must, as always, check OP 0 for the latest current technical source on the subject.

CHAPTER 9

TEST EQUIPMENT

Because of the increasing use of electrical and electronic equipment in ordnance, and because you are about to advance to a leading petty officer position, your responsibility in these fields is expanding. Now you must demonstrate your ability to inspect, test, and repair electrical and electronic controlled power drives, and analyze all types of electrical, electronic, and mechanical system malfunctions. You also have to be able to make phase, balance, and feedback adjustments to servoamplifiers and to diagnose intermittent, recurring, and interacting electrical and electronic malfunctions and to recommend inspection procedures which will prevent their recurrence.

To perform these tasks, you must, of course, have a thorough knowledge of how your equipment operates. You must also conduct a maintenance program designed to prevent, or minimize, possible casualties. When malfunctions occur in your equipment, you should be prepared to locate the trouble and repair it, using the aids furnished by the Navy. These aids include test equipment, wiring diagrams, schematics, and system maintenance publications.

Some of the test equipment you have actually used, others you have seen demonstrated. As a second class Gunner's Mate you have had numerous opportunities to use test equipment such as voltmeters, ohmmeters, and ammeters to measure values of a-c and d-c voltages, resistance and current. Other test equipments such as those used to test servosystems you have seen demonstrated by leading Gunner's Mates and yard personnel. Any weapon system equipment is only as efficient as the test equipment used in its maintenance. Proper operation and knowledge of test equipment must become one of your skills in order that you can be effective as a Gunner's Mate.

Some of the newer, more sophisticated weapon systems have automatic test equipment built right into the system to help you locate casualties. These equipments must be maintained and it will be your job to ensure that they are kept in top operating condition at all times. Test equipments are the tools of your trade, you MUST know how to use them to check and repair the equipments of your assigned system.

Ordnance test equipment includes various electrical, electronic, hydraulic, and mechanical test sets, meters, and measuring instruments, designed and constructed to perform tests of one or more specific types. Test equipment can be classified roughly as either general purpose or special purpose.

General purpose test equipment is used in performing a specific type or types of tests on a variety of ordnance equipments or systems. Examples of general purpose test equipments are: multimeters, tube testers, oscilloscopes, oscillographs, signal generators, and hydraulic test kits.

Special purpose test equipment is used in performing a specific type or types of tests on a specific type of ordnance equipment or systems. Examples of special purpose test equipments are ASROC test sets Mk 363 and Mk 357, 5/54 dummy fuze test gage, battery alignment test equipment, and gun bore erosion gages.

The purpose of this chapter is to provide an overview of the Navy's use of general purpose and special purpose test equipments used with ordnance equipment. Also to explain safety precautions when working with test equipment and to describe the types and purpose of weapon system tests conducted during maintenance, installation, troubleshooting, and planned frequence testing.

Most of the general purpose test equipment used with ordnance equipment is explained in GMG 3 & 2, NAVPERS 10185-A. Also explained in GMG 3 & 2 are many maintenance groundwork procedures which help keep a weapon system in the fight during action. Before reading this chapter you should review the material on maintenance and test equipment in GMG 3 & 2. The following is a general review of some of the maintenance and test equipment subject matter covered in GMG 3 & 2.

MAINTENANCE

Maintenance of ordnance equipment falls roughly into several basic categories: electrical, electronic, hydraulic, and mechanical maintenance. All of these categories make up a system maintenance program which falls into two main classes.

Preventive (routine) maintenance, in which you conduct periodic checks and inspections of ordnance equipments and repair the more simple and obvious malfunctions.

Special corrective maintenance, which is required when casualties occur in spite of a preventive maintenance program, and are of such a nature that they are not easily located or repaired.

ROUTINE MAINTENANCE

A large part of your daily activities will be spent in conducting routine preventive maintenance. This type maintenance program should include thorough, daily transmission checks. Casualties uncovered here usually are in an early stage, and correcting them is a simple matter. The remedy in some cases requires only enough electrical background to follow the detailed instructions outlined in the equipment OP.

Most of the trouble in electrical apparatus and wired systems is due to or indicated by:

1. Moisture.
2. Lubrication penetration.
3. Open circuits caused by loose connections or cable breaks.
4. Shock.
5. Corrosion.
6. Abrasive wear of insulation.
7. Pitted contacts of circuits breakers, switches, and contact makers.
8. Fuse failures.
9. Overload functioning of circuit breakers.

Note how many of the above can be prevented or corrected during your daily maintenance program.

MOISTURE is a major problem, especially in electrical equipment located topside. To reduce this problem, watertight housings for panels and terminal boards must be kept securely closed. Gaskets must be replaced if they deteriorate. Surface mositure on panels, terminal boards, etc., may be removed with dry, absorbent cloth. Many units are provided with drain plugs to drain off excess moisture.

To be effective, LUBRICATION must be adequate and consistent. The recommended types and frequency are shown on lubrication charts. Bear in mind however, that excessive lubrication can cause almost as much harm as lack of lubrication. Excess lubricants in an electric motor or amplidyne may work into the windings, causing failure of the unit. Do not attempt to lengthen the interval between lubrications by increasing the amount of lubricant applied. Do not, under any circumstances, lubricate the surface of electrical contacts.

OPEN CIRCUITED CONDUCTORS usually require work with a meter to locate. Some breaks in conductors, however, happen intermittently (now and then), as in the case of signal transmission cables. Portions of these cables are twisted during mount train. Breaks happening here would be indicated by erratic operation of the mount. Erratic operation may also be caused by terminals on terminal blocks and panels loosened by the shock of firing. These terminals should be checked and tightened regularly.

PITTED CONTACTS are frequent sources of trouble. Correct this condition by the use of crocus cloth. Using coarse sandpaper or a file may leave scratches deep enough to encourage arcing.

FAILURE OF FUSES and the functioning of overload relays are proof of trouble in their related circuits. Before replacing blown fuses, a search should be made for the cause—usually grounds or shorts in the circuit.

Adjustments of electrical equipment are made for a variety of reasons. The settings of the train and elevation power-drive balance and gain adjustments of amplidyne drives, for example, should be rechecked when tubes in their circuits are replaced. Furthermore, readjustments on some equipment are necessary due to changes in climate, or when adjustments are thrown off by shipboard vibration.

For the most part, the procedures for electrical adjustments are spelled out in the equipment

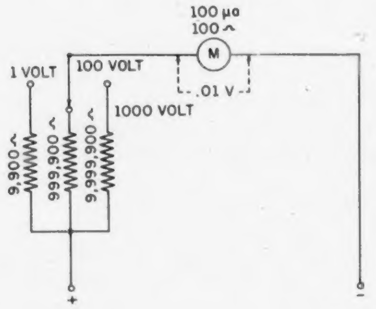
OPs. However, keep in mind that, before attempting to correct faulty mount operation by electrical adjustments, you should assure yourself that the trouble is definitely due to a faulty adjustment. Indiscriminate tampering with adjustments to correct difficulties that are actually due to wiring mistakes or faulty meter readings will only increase your headaches.

TEST INSTRUMENTS

From our study of electrical measuring instruments (meters) explained in GMG 3 & 2, NAVPERS 10185-A, we know that a knowledge of electrical test equipment is necessary for maintaining ordnance equipments. As a first class or chief you must now become more proficient in the use of these instruments because you must be able to explain their use to your strikers. We will review some meters commonly found in ordnance systems. They are listed with a brief description of their functions.

VOLTMETER

The voltmeter measures voltage (also called potential difference, or EMF, or voltage drop). It utilizes the basic meter movement by placing it in series with a high resistance. The range of the voltmeter is extended by incorporating several of these fixed resistors. A schematic of a multirange voltmeter circuits is shown in figure 9-1.

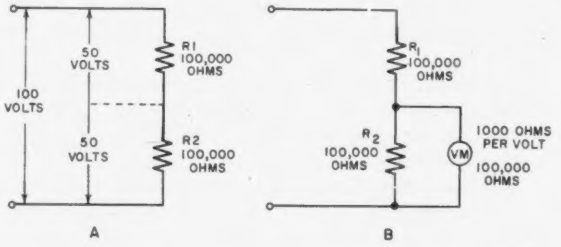


53.4
Figure 9-1.—Multirange voltmeter.

You can select the proper scale by operating a selector switch. To protect the meter, use the highest scale to commence a voltage test. The scale can then be brought down progressively until the needle rests near the center of the dial face, where readings are more accurate.

The sensitivity of a voltmeter determines how accurately it can measure the voltage in a circuit. Sensitivity is usually indicated on the face of the meter in ohms per volt. Total meter resistance can be determined by multiplying scale setting by the meter sensitivity. For example, the sensitivity indicated on a small, portable meter is 1000 ohms per volt. If a meter of this kind is set on a 10-volt scale, the overall resistance of the meter would be 10,000 ohms.

You can understand the importance of meter sensitivity rating if you look at figure 9-2. Here you have two resistors in series, each 100,000 ohms, and a supply voltage of 100 volts direct current. In figure 9-2A, the voltage drop across each resistor will be the same (50 volts) because the resistors are equal. By placing a voltmeter across the bottom resistor, R2 (fig. 9-2B), you would expect to get a reading of 50 volts.



53.5
Figure 9-2.—Importance of meter sensitive.

If the d-c voltmeter you used had a full-scale reading of 100 volts, it should read half scale. But assume the meter sensitivity is only 100 ohms per volt. That means the total resistance of the meter is 100 x 1000 or 100,000 ohms. You now have two resistors in parallel (the meter resistance and R2) each with a resistance of 100,000 ohms, the equivalent resistance being 50,000 ohms. Therefore, two-thirds of the supply voltage will appear across R1, leaving 33 1/3 volts to appear across R2 and the voltmeter. The reading is in error by 16 2/3 volts.

Now use a more sensitive meter—one rated at 25,000 ohms per volt. With the same full-scale reading of 100 volts the total meter resistance is 100 x 25,000, or 2,500,000 ohms. The total resistance of this meter in parallel with R2 is 96,000 ohms. Using this meter, the voltage read across R2 will be 49 volts.

On circuits containing low resistances, then, a meter of low sensitivity may be used. But in many electronic circuits, resistances are high and the current in them very small. If a meter of low sensitivity is used in such circuits, the current drawn by the meter will significantly lower the voltage you are trying to measure and the meter reading will be incorrect.

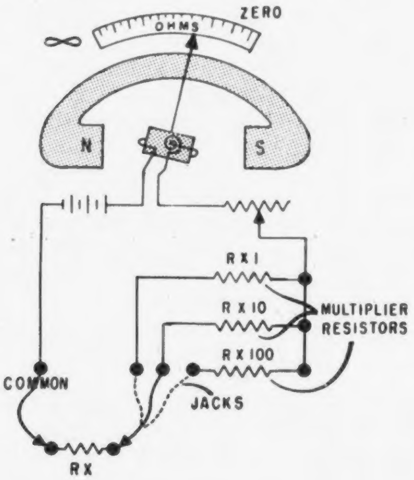
OHMMETER

The ohmmeter is widely used to measure resistance and to check circuit continuity. It is constructed with a basic meter movement and a self-contained source of voltage, usually a 3-volt battery. Before using the ohmmeter on any circuit, the circuit must be deenergized.

The range of the ohmmeter can be increased by multiplication features. These are different sized resistors which can be placed in series with the ohmmeter's circuit, as shown in figure 9-3.

On some ohmmeters, you select the proper multiplication scale by operating a selector switch. On others, separate test lead jacks are used for different scales.

Before using an ohmmeter to test a circuit, the meter should be adjusted or "zeroed." This will cancel out the internal resistance of the meter, and compensate for the voltage variations of the self-contained battery. To calibrate an ohmmeter for proper operation on a selected range, first short the test leads together. (While the leads are shorted, meter current is maximum and the pointer deflects a maximum amount, to somewhere near the zero position on the ohms scale.) Then adjust the variable resistor (rheostat), with the leads shorted, to bring the pointer of the meter to rest exactly on the zero graduation. This indicates zero resistance between the test leads. The zero reading on most series-type ohmmeters is at the right-hand end of the scale.



53.6

Figure 9-3. — Ohmmeter with multiplication jacks.

MEGGER

The megger is actually an ohmmeter that is capable of measuring resistance in millions of ohms (megohms). Resistances such as these will be encountered while testing conductor insulation for breakdown. The high potential needed for these tests is furnished by an internal hand-driven generator.

Meggers supplied to ships normally are rated at 500 volts. They are equipped with friction clutches so that, when the generator is cranked at higher than its rated speed, the clutch will slip, and the output voltage will not exceed its rated value. Like the ohmmeter, the megger is used on circuits only after power to the circuit has been secured.

Use of the Megger

As explained earlier in this chapter, the MEGGER is actually an ohmmeter which is capable of measuring resistances in millions of ohms. This is possible because of the high voltage (500 volts) generated by the hand-driven generator in the meter.

High voltages such as these are necessary to test conductor insulation, or insulation in which breakdown under high voltage is suspected. The 3 volts provided by the ohmmeter may not be sufficient to uncover this breakdown.

The megger can be used, with care, to test for continuity and grounds, keeping in mind that many of the elements in gunnery circuits would be damaged if subjected to 500 volts.

MULTIMETER

This is simply a multipurpose meter that can measure resistance, current, or voltage. It is portable, and eliminates the need for carrying several meters.

The front panel is constructed and labeled in such a way as to be almost self explanatory. Selector switches on the front panel are used to select the type of measurements to be taken, the resistance, voltage and current ranges to be tested, and also has selected pin jacks to take high voltage readings.

TUBE TESTER

Tube tester TV-3B/U is designed to test and measure the mutual conductance of electron tubes of the receiving types, and many of the smaller transmitting types. Rectifier and diode tubes can be checked for emission. Two other tube tests conducted with this meter are the short test (for shorts between tube elements) and the gas test.

Use of the Tube Tester

Although each electron tube purchased by the Navy has been thoroughly tested, it is possible for tubes to be damaged in shipment, storage, or handling. Therefore, a tube should be tested before it is used.

Electron tubes do not last indefinitely. Coated cathodes lose their power to emit electrons because the coating flakes off. Likewise, impregnated emitters of filament-type tubes become depleted with age. Defective seals permit air to leak into the tube and "poison" the emitting surface. Vibration or excessive voltages may cause internal shorts or opens. Whenever electronic equipment operates subnormally, one of the first maintenance procedures is to check the tubes.

Types of Tube Testers

Two types of tube testers are in general use. One, the EMISSION type, indicates the relative value of the tube in terms of its ability to emit electrons from the cathode. The second and more accurate type is the MUTUAL CONDUCTANCE (TRANSCONDUCTANCE) tube tester. This type not only gives an indication of the electron emission, it also indicates the ability of the grid voltage to control plate current.

The tube tester used with ordnance is of the mutual transconductance type; this tester is in general shipboard use. The four most common tests you may conduct with this instrument are the (1) short circuit test, (2) mutual conductance test, (3) emission (rectifier) test, and (4) gas test.

The tube tester has a roll chart indicating the tubes that may be tested. Listed opposite the tube designations is a series of numbers and letters which indicate the setting of each switch and potentiometer, and also the correct pushbutton to use. These switch positions connect the tube into a circuit that is comparable to the operating circuit of the tube. When the potentiometers are adjusted to the values indicated on the chart, the correct operating voltages are applied to the tube so that it can be checked under operating conditions.

LINE VOLTAGE.—Line voltage applied to the primary of the power supply transformer is adjusted by means of a variable resistor in series with the primary power leads. Correct line voltage adjustment will ensure the correct voltages required to test tubes under circuit operating conditions.

SHORT CIRCUIT TEST.—The short circuit test is used to determine if there is a short between any two elements within the tube. The SHORTS switch connects the various elements of the tube under test to a voltage source in series with a neon lamp; the lamp glows if there is a short between the elements.

EMISSION TEST.—Rectifier and diode detector tubes having no grid or amplification are tested for emission rather than for mutual conductance.

To test these tubes, first set all switches and potentiometers to the positions indicated on the roll chart. Place the tube in the proper socket and adjust the line voltage. Then push the designated button. The meter will indicate above the rectifier mark for a good tube. If the reading is below the mark, the tube is weak or gassy.

MUTUAL CONDUCTANCE TEST.—Mutual conductance tests are performed on amplifier tubes by positioning the selector switches and potentiometers as indicated by the roll chart. After placing the tube in the proper socket, and adjusting the line voltage, a short circuit test can be conducted. To make the manual conductance test, the designated button is pushed. The meter will indicate the quality of the tube. A reading lower than that given on the roll chart indicates a weak tube. A higher reading may indicate a gassy tube.

GAS TEST.—The gas test is used to determine the presence of gas in the envelope of the tube.

This test is NOT used for gas-filled tubes such as thyratrons. The gas test is usually made after the quality test, and therefore the switches and potentiometers are in the required positions. If the meter reading increases when the GAS TEST button is pushed, the tube is gassy.

Tube Tester Limitations

In general, the tube testers do not COMPLETELY indicate the performance. A complete testing instrument that would duplicate the operating conditions of ALL circuits and correctly evaluate the performance of ALL tubes to be used in it is impracticable. As a rule, therefore, only dead, shorted, or extremely weak tubes should be discarded purely on the basis of a tube tester check.

VACUUM TUBE VOLT METER (VTVM)

One of the most helpful developments in meter type measuring devices for testing electronic equipment, is the incorporation of the vacuum tube in the measuring instruments itself. The basic meter movement is connected into a vacuum tube circuit in such a way as to indicate a current which is proportional to the signal applied between the test prods. This electron tube voltmeter, called Vacuum Tube Volt Meters (VTVM), is better than the ordinary multimeter because it isolates the meter movement from the circuit under test, and utilizes the vacuum tube's capabilities as an amplifier and rectifier. These greatly increase the sensitivity of the measuring system beyond that established by the meter movement itself. Moreover, it extends the frequency range of the meter for up into the hundreds of kilocycles region. Special probes are used to further extend these frequency limits to hundreds of megacycles.

Another advantage of the VTVM, is that the input impedance is not only high, but is constant for all d-c voltage ranges; in contrast to the impedance of the multimeter which varies according to the full scale voltage being used. Electronic voltmeters usually are incorporated into multimeters with an ammeter, or milliammeter, and an ohmmeter. Multimeter ME-25 B/U, figure 9-4, which is in current shipboard use, is an example of this type.

We will discuss some of the techniques employed in the use of meters. As you develop your skill, you will find many useful variations and techniques.

Continuity Test

The purpose of this test is to ensure that a circuit is a complete or continuous one. The casualties to be found are open circuits. An open circuit is one in which the flow of current is interrupted by a broken wire, defective switch, etc.

An ohmmeter (which contains its own batteries) is excellent for a continuity test. Normally, continuity tests are performed on those parts of a circuit in which the resistance is very low—for example, switch contacts and wiring between circuit components. An open circuit is indicated on the meter as a very high or infinite resistance.

When checking circuit continuity, the ohmmeter should be set on the lowest range. If a medium or high range is used, the pointer may indicate zero ohms, although the resistance may be as high as 500 ohms.

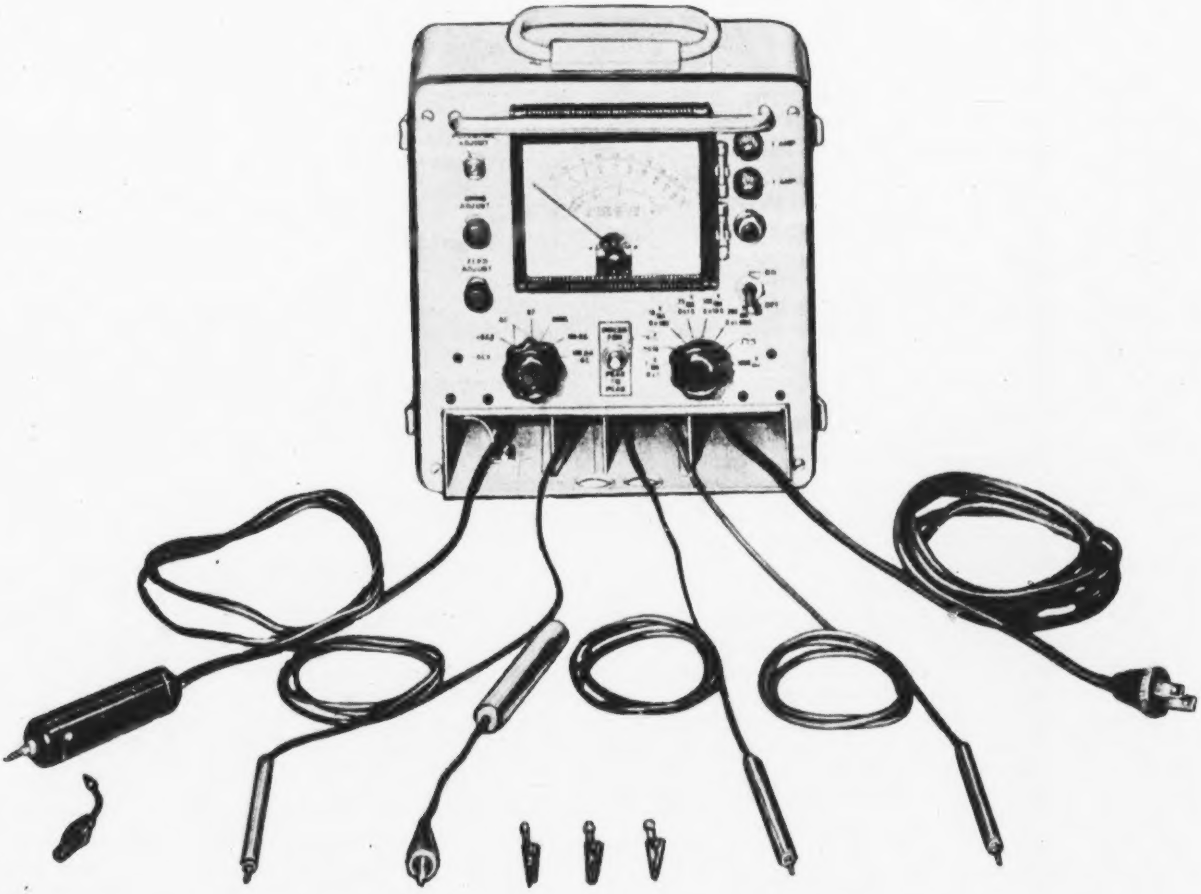
At times you will find that the test prongs of the meter will not reach the ends of the circuit to be tested. An example of this is a cable reaching between two compartments or decks. In this case, sound-powered phones can be used to check the circuit for continuity. Hand sets equipped with alligator clips are the most commonly used type. This test is conducted as follows:

1. Secure all power to the circuit.
2. Disconnect the circuit to be tested at both ends.
3. Attach the phones to the disconnected leads.
4. Talk.

If the circuit is complete, it will transmit the voice.

Another method of conducting continuity tests is by means of a test lamp. This method is commonly used in checking firing circuits and electrical firing cutout mechanisms. We can use the same principle by using batteries instead of the normal 20-volt firing circuit power to cause the test lamp to light.

You may have discovered that breaks, or opens, in cable conductors are sometimes intermittent. The right indication of this type of casualty would be erratic operation of the mechanism controlled by the circuit. Intermittent



4.133

Figure 9-4.—Electronic multimeter ME-25B/U.

opens may often be located by flexing the suspected cable while it is under continuity test.

Voltage Test

The voltage test is made with the power applied. Therefore, prescribed safety precautions MUST be followed to prevent injury to personnel and damage to the equipment. You will find in your maintenance work that the voltage test is of utmost importance. It is used not only in isolating casualties of major assemblies, but also in maintenance of subassemblies, units, and circuit. Before checking a circuit voltage, first check the power source to make sure that the normal voltage is being impressed across the circuits. During troubleshooting this check is of special importance, as improper supply voltages can cause odd effects.

Obviously, the voltmeter is used for voltage tests. In using the voltmeter make certain that the meter used is designated for the type current (a-c or d-c) being tested and has a scale of adequate range. Since defective elements in a circuit may cause higher than normal voltages to be present at the point of test, the highest voltmeter range should be used at first. Once a reading has been obtained, determine if a lower range scale can be employed without damaging the meter movement. If so, use the lower scale, so as to obtain a more accurate reading.

Many schematics indicate proper voltages at many test points. Thus if a certain stage is suspected, you can check the voltage by placing the voltmeter test leads between the designated test points. The voltages obtained at the meter should be the same as those given on the schematic. Many OPs also contain voltage charts. These charts usually indicate the sensitivity of the meter used to obtain the voltage readings for the chart. To obtain comparable results, you must use a voltmeter of the same sensitivity as that specified.

Electronic voltmeters are used, in general, in much the same way as the nonelectric voltmeter except that they have a greater and more varied range of uses.

Resistance Test

The resistance of a circuit portion of a circuit, or circuit elements usually is measured with the ohmmeter. The meter is connected into the circuit after it has been "zeroed" and power to the circuit secured.

Selection of the proper scale (low, medium, high) is important in making resistance tests. To check a circuit of low resistance, use the lower range of the ohmmeter. If a high range is used, the meter may indicate zero, even though appreciable resistance is present in the circuit. Conversely, to check a circuit containing high resistance select the highest scale, since the low range scale may indicate infinity though the resistance is less than a megohm.

While conducting resistance tests, take into account that other circuits containing resistance and capacitance may be in parallel with the circuit being tested. To obtain a correct reading, disconnect these parallel circuits.

There are other factors which may lead you to erroneous conclusions when you measure resistance. Transformers, for example, should be allowed to cool before testing. There are also tolerance values for transformer windings, generally between 1 and 5 percent. As a rule, suspect a transformer which shows a resistance deviating by more than 5 percent.

Most general-purpose resistors have a tolerance of 10 percent. As a rule, the ordinary resistors used in circuits are not replaced unless their values are off more than this.

Test For Grounds

Grounded circuits are caused by some conducting part of the circuit making contact, either directly or indirectly, with the metallic structure of the ship. Grounds may have several causes. The two most common are perhaps the fraying of insulation, which allows the bare wire to come into contact with the metal ground, and moisture-soaked insulation.

Grounds usually are indicated by blown fuses or tripped circuit breakers. However, a high resistance ground may occur where not enough current can flow to rupture the fuse or open the circuit breaker.

In testing for grounds, an ohmmeter may be used. By measuring the resistance to ground at any point in a circuit, it is possible to determine if that point is grounded. Before conducting this test you should check the associated wiring diagrams for intentional grounds. These grounds must be disconnected from the circuit under test.

Test for Shorts

A short circuit, other than a grounded one, is one in which two conductors accidentally touch each other—either directly or through another conducting element. Two conductors with frayed insulation may touch and cause a short. Too much solder on the pin of a connector may cause a short to the adjacent pin. In a short circuit, enough current may flow to blow a fuse or open a circuit breaker.

As when checking for a ground, the device used for checking a short is the ohmmeter. When you measure the resistance between two conductors, a short between them will be indicated by a low resistance reading.

Shorts occur not only in cables, but also in such components as transformers, motor windings, and capacitors. The major test method for detecting shorts in these components is a resistance measurement. The resistance indicated by the meter is then compared with the resistance given on schematics or in the equipment OP.

SHIPBOARD TESTS AND TEST EQUIPMENT

Weapon system shipboard performance tests determine whether the elements of a ship's weapon system functions satisfactorily under various operating conditions. Most performance tests are conducted annually. Note, however, that existing conditions such as a suspected malfunction, etc. may require that certain tests be performed more frequently.

Typical reasons for conducting such operational performance tests are new installations, regular yard overhaul, replacement of major components, or repair of a major casualty. In case of major casualties, only the affected portion of the system need be activated and tested.

Operational performance tests are also required to determine whether a gun mount or launcher's train and elevation power drives follow order signals accurately, or to check specific equipment such as fuze setters, and ammunition handling equipment.

Regardless of the purpose or the frequency that these performance tests are conducted, the personnel conducting the tests must be familiar with both the testing procedure and the equipment used. Each major unit of a ship's weapon system (gun mount, launcher, director, and other ordnance equipments) have separate weapon system ODs which list all the individual shipboard tests conducted at the time of initial installation.

COMPARING PERFORMANCE DATA

Following their shipboard installation, units of a ship's weapon system were subject to a complete performance test as detailed in a shipboard Installation Test Instruction OD for each unit installed. The results of these tests were logged in the ship's copy of the OD for future reference. The resultant test tracings of the installation performance tests are reproduced as an appendix to each OD. After conducting performance tests of a gun mount or launcher, compare the test results with those obtained at installation. The information obtained from these tests could result in detection of a significant performance deterioration which can warn of impending failure, and may indicate the need for corrective maintenance, repair, or overhaul.

The tests listed in the installation ODs generally are arranged so that each group of tests are described on a test lead sheet which is followed by one or more test work sheets. The work sheets provide scales to facilitate the reading of the oscillograph traces for the various tests, figure 9-5. After completion of the tests, the oscillograph traces should be attached to the respective work sheets. A list of shipboard Installation Test Instructions ODs can be found in OP 0 and OD 39397, Index of Technical Manuals For Conventional Ordnance. When performing any tests employing a graph type paper such as that used with an error recorder, consideration should be given to the characteristics of the trace being conducted. No attempt should be made to duplicate any previous traces because there are too many variables involved. You should, however, endeavor to obtain results that are within the tolerances recorded on the work sheet for the test being conducted.

Testing Problems

Information taken from some current surface ships INSURV inspection reports revealed that one of the major deficiencies found within a weapons system was that many of the system component power drives were sluggish and that system performance dynamic tests were not conducted or were out of date. It was also found that ships having test equipment such as dummy directors and error recorders were not using them due to the fact that personnel were unable to demonstrate their use. As a first class or chief gunner's mate, it will be your responsibility to insure that such tests are conducted.

The following information will explain some of the types of test equipment used to conduct operational performance tests and also supply information on the types of test traces, the reading of test traces, the precautions to be observed, and the methods used to calibrate the recording oscillographs.

TYPES OF TRAIN AND ELEVATION TRACES

Normally, three types of test traces are taken with test instrumentation. The three are: B-end error traces, B-end velocity traces, and B-end position traces.

B-end error trace voltages are obtained from the 36X CT geared to the B-end response shafts in the respective receiver regulators. The synchro rotors are geared to the 36X response in the regulator while the stators are connected electrically to the stators of the 36 X synchro generators in the local or external test director. The rotor output voltages, which are 400 Hz a-c output, represent the error between the local or external director and the B-end response shaft. The output voltages are circuited through a limiter and demodulator test unit and then recorded by an oscillograph.

OD 8948

TRAIN POWER FAILURE

SHEET 6.21-1

OPERATION	DATE & INITIALS
The gun was subjected to a power failure while operating at maximum gun train velocity. The following data was observed. (Set the local director and the external director at stationary order signals 120 degrees apart. Transfer control from one director to the other allowing the gun to reach maximum velocity, then set the power failure switch SMY11 to MAIN MOTORS when the gun is not less than 20 degrees from the stationary signal position.)	

Test No.	Direction	Maximum Deceleration (deg/sec^2)	Travel Between Power Failure and Stopped (degrees)
31	Right Train		
32	Left Train		

Test No. 31
Input Signal:
Fixed displacement
120 degrees

Record B-end output shaft velocity and position with a Brush double channel direct inking oscillograph. Superimpose power failure pip on position trace.

Each time division equals 0.04 seconds.

B-End Velocity Trace

0°/sec ____

25°/sec ____

50°/sec ____

B-End Position Trace

0 deg ____

.5 deg ____

1.0 deg ____

2.5 deg ____

53.292
Figure 9-5. — Test Work Sheet.

B-end position traces are obtained from the same 36X CT that furnishes the B-end error trace voltages. Through proper switching of the test equipment, the output voltages produced will indicate B-end position and not B-end error. The position output voltage also is circuited to the limiter and demodulator units and recorded by the oscillograph.

B-end velocity trace voltages are obtained from the d-c tachometer generators located in the respective receiver regulators. These tachometer generators are geared directly to the B-end response gearing and furnish a d-c voltage that is proportional to the B-end velocity. The tachometer output is circuited through test instrumentation and then recorded by the oscillograph.

TEST INSTRUMENTATION

The following is a list of some of the gun and ASROC launcher test equipments used during performance testing.

Limiter and Demodulator Units
Standard Oscillographs
External (Dummy) Directors
Error Recorders (Oscillographs)

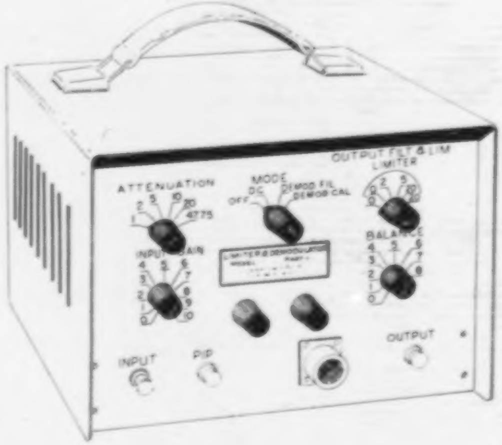
LIMITER AND DEMODULATOR

The limiter and demodulator unit is a portable electronic test instrument used with a standard oscillograph or other galvonometer type recording instruments which performs the following basic functions.

1. A-c amplification with demodulation and filtering and,
2. D-c amplification.

The limiter and demodulator contains an RC low pass filter which can be used in all modes of operation. In addition, provisions are made within the test circuit to superimpose an auxiliary pip onto a position test trace. Pips indicate switch or relay actuation points on a trace to simulate power failure circuitry.

The limiter and demodulator consists essentially of an a-c amplifier, an attenuator, a demodulator, limiters, filters, and a d-c amplifier. The output of the d-c amplifier drives the recording instrument. Control switches are located on the front of each limiter and demodulator which allows three modes of operation (fig. 9-6).



53.298
Figure 9-6.—Model G limiter and demodulator.

Mode of Operation Switch

This switch is used to turn the power on and to obtain the three basic functions of the instrument. These functions are obtained by selecting one of the following switch positions: DC (direct current), DEMOD. FILT. (demodulation filtering), and DEMOD. CAL. (demodulation calibration).

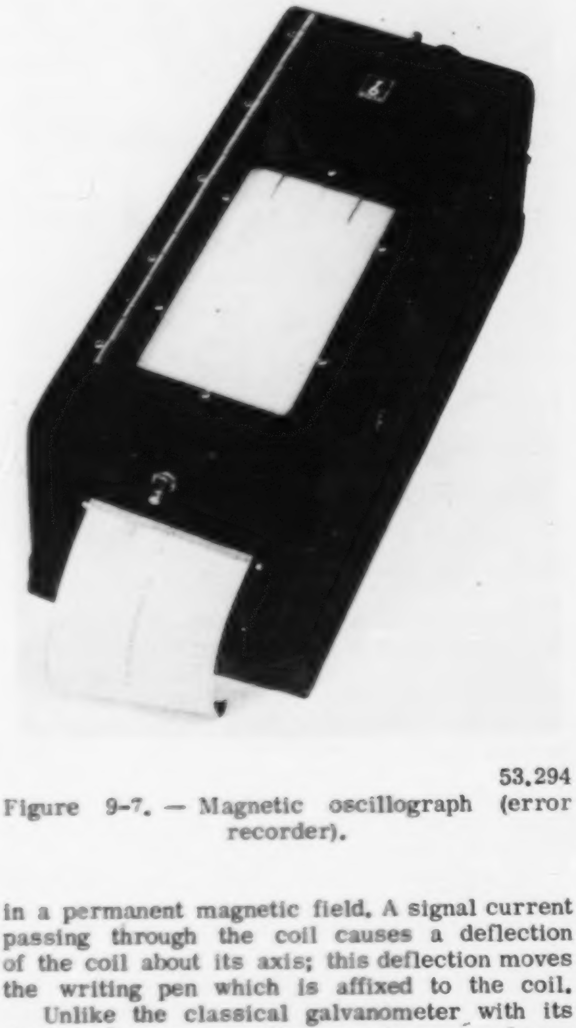
At the DC setting, the limiter and demodulator power amplifies d-c input signals. This setting is used for velocity test traces.

At the DEMOD. FILT. setting, the instrument amplifiers demodulate and filter a-c signal inputs. This setting is used for error and position test traces.

At the DEMOD. CAL. setting, the signal input circuit is opened an a-c calibrate voltage is introduced.

STANDARD OSCILLOGRAPH

The oscillograph figure 9-7, provides a flat frequency response from a d-c input signal up to 100 Hz. There are three standard chart paper speeds: 5, 25, and 125 mm per second. The models is used in most weapon systems are equipped with ink writing stylus (pens). The penmotors employ the familiar d'Arsonval galvanometer type mechanism in which a coil is used to deflect a pen. A penmotor for each pen has a coil supported by a bearing mounted



53.294

Figure 9-7. — Magnetic oscillograph (error recorder).

in a permanent magnetic field. A signal current passing through the coil causes a deflection of the coil about its axis; this deflection moves the writing pen which is affixed to the coil.

Unlike the classical galvanometer with its delicate hair springs, the penmotor uses a heavy torsion spring to maintain the zero position of the coil. The resonant frequency of the penmotor is established by the stiffness of the torsion spring and by the mass of the combined coil and pen assembly. Resonance is at a relatively high frequency, about 47 Hz, and the system has the necessary stiffness to maintain a high degree of linearity in spite of the variable effects of pen tip friction on the writing medium. The flatness of frequency response with constant voltage input is determined by a number of factors which must be in proper relationship to obtain the required damping. The mass of the moving system, the stiffness of the torsion spring, the magnetic flux, and the relationship of coil turns and resistance must all be carefully correlated in the penmotor design to obtain critical damping (prevent oscillation). Frequency response of the penmotor is flat at 60 percent of resonant frequency or about 30 Hz when the penmotor is properly matched to its driving source. The penmotors operate at about 60 percent of critical damping. This provides the optimum balance between transient and frequency response.

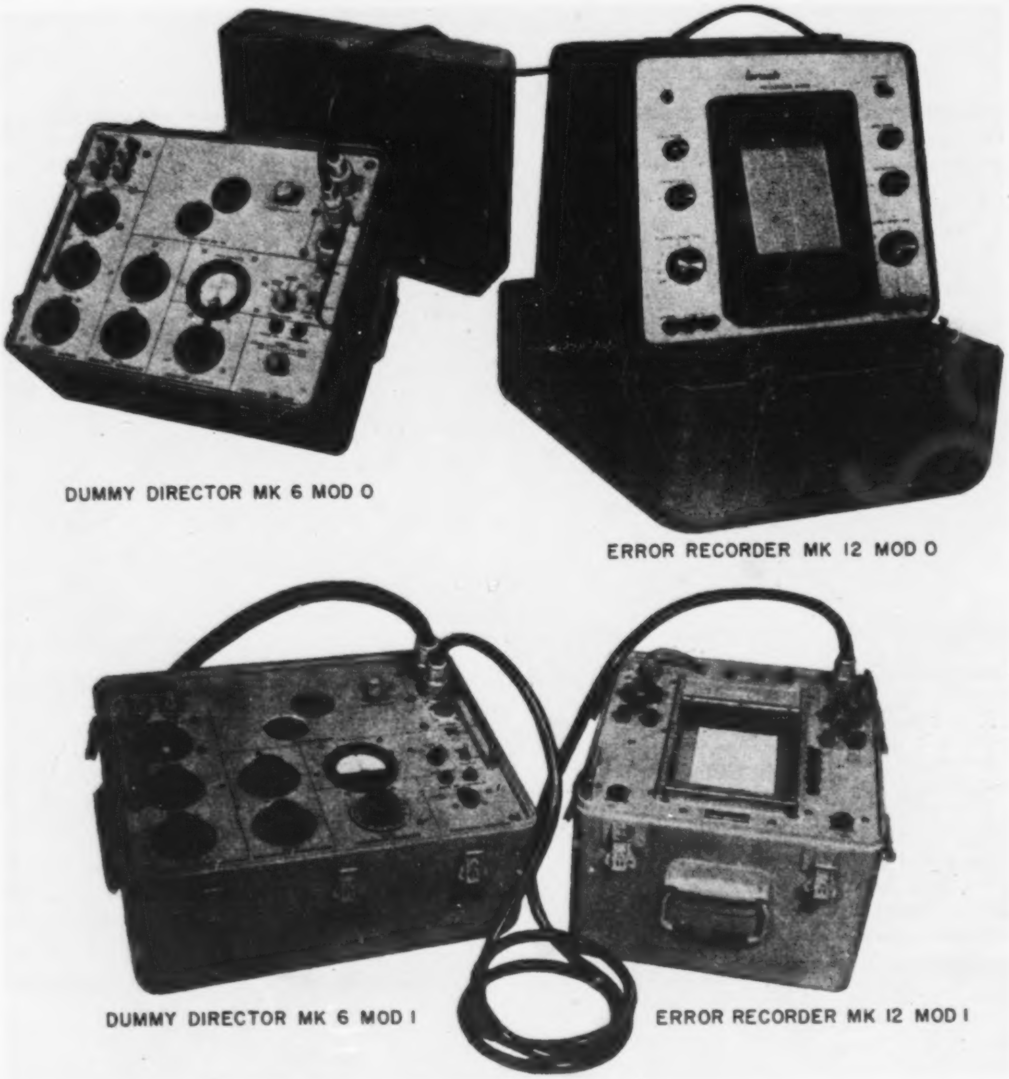
The oscillograph includes a plug which must be connected to a 115 V, 60 Hz source. Two receptacles are provided for the inputs to each of the penmotors.

ERROR RECORDER

Error Recorder Mk 12, figure 9-8, like a standard oscillograph, is used to record the response of the power drive when they are being controlled by, an external director. These recorded responses are voltages that represent the error, position, and velocity of the B-end.

Visual indications are recorded in the form of a trace. The methods of recording the trace differ: the Mk 12 Mod 0 recorder utilizes an inking stylus, whereas the Mod 1 recorder utilizes a thermal stylus and heat-sensitive recording paper. Two responses can be recorded simultaneously on dualchannel recording paper. In addition, there is a stylus on the outer edge of each channel of the tape that can be used for system sequence operation timing. Each channel occupies half of the width of the paper, and is marked with 20 lines ruled lengthwise. The lines are spaced one millimeter apart and each 5th line is heavy. Lines, called time divisions, appear across the width of paper, and are also spaced one millimeter apart with heavy 5th lines.

The amount of response voltage being recorded, at any instant during the test, is indicated by the number of lines that the trace is displaced from the centerline at the instant. Therefore, the trace is a graph of the response voltage versus time, with the time division lines serving a convenient measure of time. The speed at which the paper feeds through the instrument depends upon which feed push-button is selected. The speed selections are the same as those for a standard oscillograph 5, 25, and 125 millimeter per second of time. The error recorder must be calibrated to establish the amount of trace deflection, in respect to response voltage, before the testing can begin. The calibration procedures


DUMMY DIRECTOR MK 6 MOD 0
ERROR RECORDER MK 12 MOD 0
DUMMY DIRECTOR MK 6 MOD 1
ERROR RECORDER MK 12 MOD 1

55.310

Figure 9-8.—Dummy director Mk 6 Mods 0 and 1, and error recorder Mk 12 Mods 0 and 1.

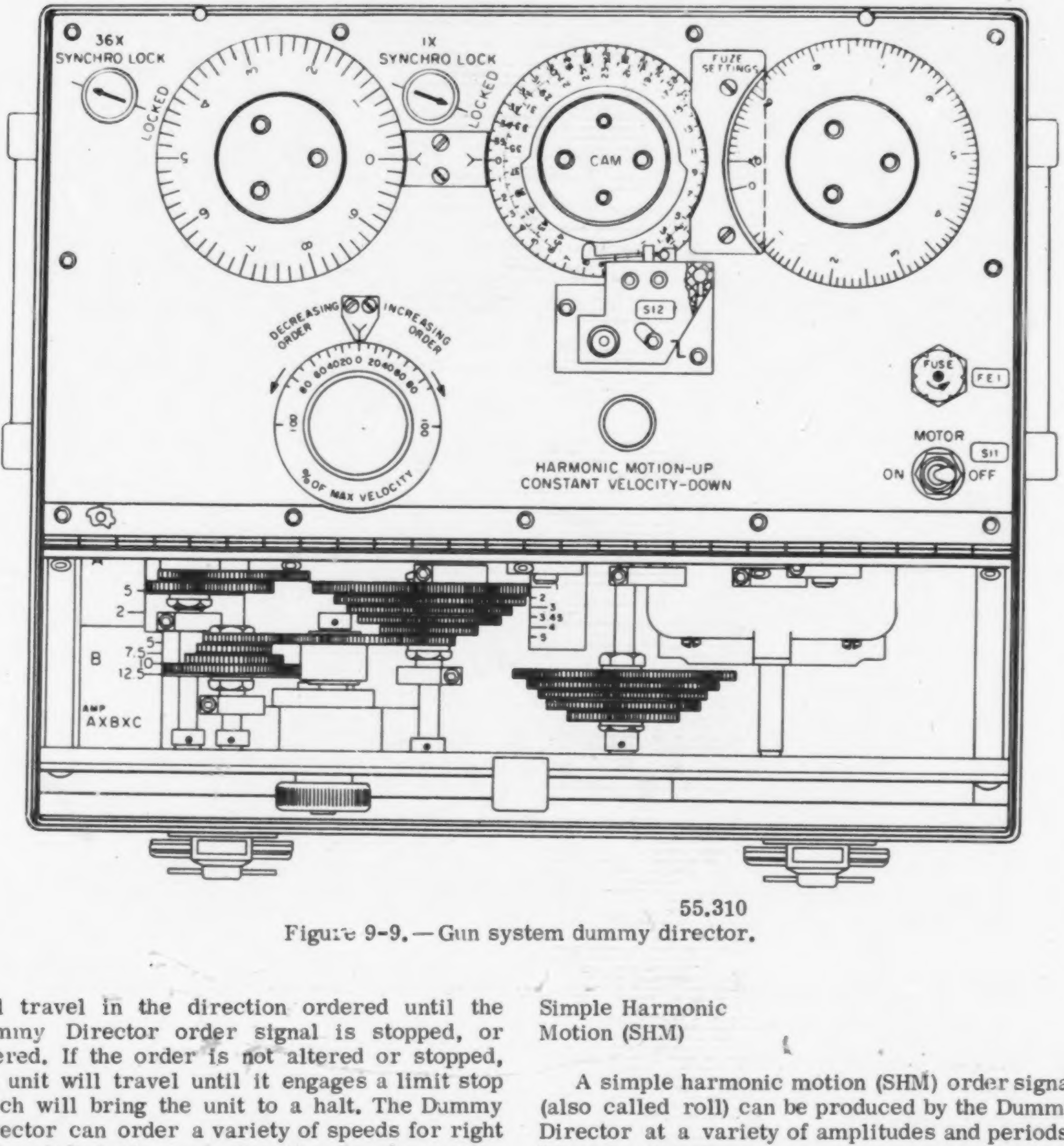
for standard oscillograph and error recorders are explained later in this chapter.

EXTERNAL (DUMMY) DIRECTORS

Dummy directors figures 9-8 and 9-9, contain synchro transmitters (generators) that generate electrical signals used to perform dynamic and performance accuracy tests of the train, elevation, and some fuze setting systems. These instruments supply three types of signals: a constant velocity signal, a simple harmonic motion signal, or a stationary signal.

Constant Velocity Signal (CV)

If a constant velocity (CV) order is selected at the director, the ordnance unit under test


36X
SYNCHRO LOCK
LOCKED
1X
SYNCHRO LOCK
LOCKED
FUZE SETTINGS
CAM
S12
DECREASING ORDER
INCREASING ORDER
% OF MAX VELOCITY
HARMONIC MOTION-UP
CONSTANT VELOCITY-DOWN
FUSE
FE1
MOTOR
S11
ON
OFF
B
AMP
AXBXC

55.310
Figure 9-9.—Gun system dummy director.

will travel in the direction ordered until the Dummy Director order signal is stopped, or altered. If the order is not altered or stopped, the unit will travel until it engages a limit stop which will bring the unit to a halt. The Dummy Director can order a variety of speeds for right train, left train, and elevation or depression of a gun barrel or launcher guide. The unit's rate of movement is constant during CV travel once the unit attains the directed speed after starting.

Simple Harmonic Motion (SHM)

A simple harmonic motion (SHM) order signal (also called roll) can be produced by the Dummy Director at a variety of amplitudes and periods. When the director commences transmission of the SHM order, the units will move from the starting point to the angle selected, stop, reverse and return to the starting point. The unit will continue to roll to an equal angle on each side of the fixed center point until the director orders are altered or discontinued.

Stationary Signal

When a manually set stationary signal is used, a position should be selected so that the units will not engage the limit stops. The stationary order signal from the Dummy Director will drive the units until it arrives at the ordered position. The unit remains at this position without further movement until the director's setting is changed.

GUN BATTERY TEST EQUIPMENT

In most gun systems, performance and dynamic accuracy tests are conducted by tender or shore activities. The reason for this is that most combat ships do not carry the test instruments aboard as part of a ship's test equipment allowance. The type of tests and the equipments used are determined by the classification of the gun mount and by the activity conducting the test.

In most new type gun batteries, such as the 5"/54 Mod 9, performance tests consist of accuracy, velocity and acceleration, synchronized error, limit stop, and power failure tests. During testing, the following should be observed and noted:

1. General smoothness of operation
2. Any excessive or abnormal noise, vibration, or other unusual operational characteristics and,
3. Any burring, scoring, or galling of the mechanical parts such as the surface of the elevating arc and pinion or of the training circle and pinion.

The following is a step-by-step description of how to align and calibrate the test equipment used during a test, how to align the power drive servo system before starting a test, and how to conduct some of the many power drive performance tests of both the train and elevation systems.

Figure 9-10, illustrates the types of test equipment used with the 5"/54 R. F. gun system and also shows the hookup between the portable and fixed test equipments.

TEST EQUIPMENT CALIBRATION

Since the oscillograph has two channels, two different traces may be taken at the same time. This allows corresponding trace results to be compared to learn more about the gun mounts operation: Normally, three types of these traces are taken with test instrumentation. They are: B-end error traces, velocity traces, and position traces. Figures 9-11, 9-12 and 9-13, show sample test traces and include a brief explanation. The B-end error trace, figure 9-11, also shows how a pip indication appears on a test trace.

Note: Always calibrate the oscillograph before recording any traces.

The oscillograph is calibrated by two different methods during gun mount testing procedures. Error and position traces are calibrated by one method; velocity traces by another. Before the oscillograph can be calibrated, it must be balanced. To balance the oscillograph recorder, disconnect the input to the penmotors by disconnecting the output from the demodulators. Turn the oscillograph recorder on and set the chart speed selector to 5. Mechanically zero both pens so they trace on the center of each channel as shown in figure 9-14.

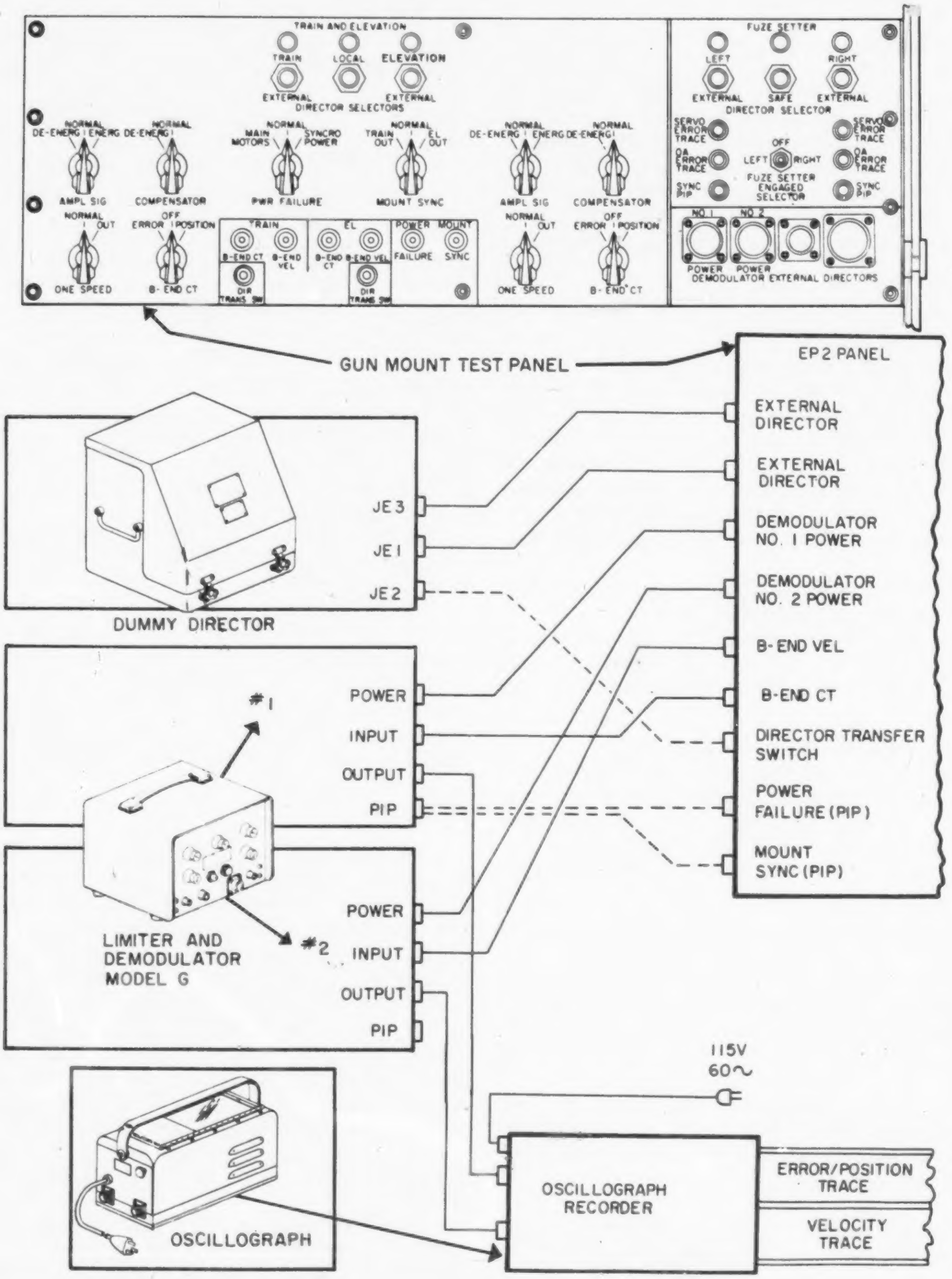
Note: Channel #1 (left) is used for velocity trace and channel #2 (right) is used for error trace.

After the oscillograph is mechanically balanced, the next step is to balance the limiter and demodulators. Reconnect the demodulators output to the oscillograph and adjust the balance control on the demodulators to again zero the pens on the oscillograph recorder trace paper so they are on the center of each channel.

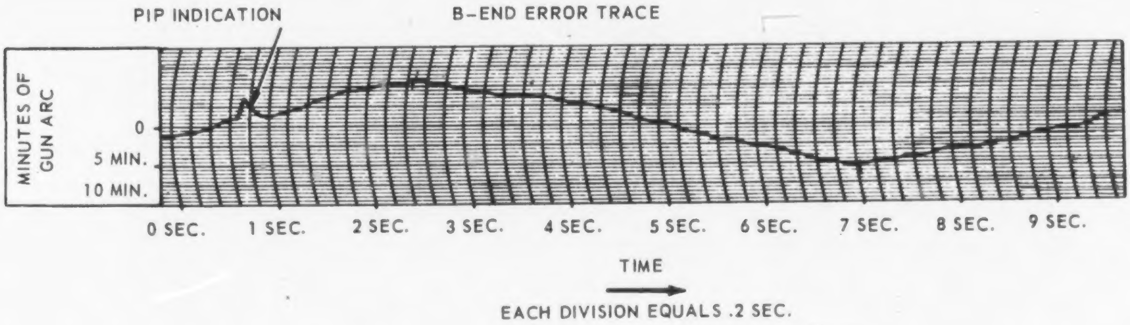
Calibrate Channel #2

To calibrate the error/position trace on channel 2, select the demodulator connected to that channel (demodulator #1, fig. 9-10). Set the demodulator mode of operation to DEMOD. CAL. and the attenuation switch at 5. Start the oscillograph recorder by pressing chart speed push button 5 MM. This causes the chart paper to run at a slow speed. At demodulator #1, adjust the input gain potentiometer for 10 lines (half scale) deflection on the oscillograph recorder chart paper. Channel #2 is now calibrated to run the desired position/error trace. Reset the demodulator by setting the mode switch to DEMOD FILT. and the attenuation switch at 47.75.

An error trace now has the following possible calibrations: 5, 10, and 20 minutes half scale deflection. A half scale deflection equals ten lines from 0 to 10 MM, figure 9-15. It also has a 2.5 degree full scale calibration. A full scale


TRAIN AND ELEVATION
TRAIN
LOCAL
ELEVATION
EXTERNAL
EXTERNAL
DIRECTOR SELECTORS
NORMAL
DE-ENERG
ENERG
DE-ENERG
NORMAL
MAIN MOTORS
SYNCRO POWER
TRAIN OUT
EL OUT
AMPL SIG
COMPENSATOR
PWR FAILURE
MOUNT SYNC
OUT
OFF
ERROR
POSITION
TRAIN
EL
POWER
MOUNT
B-END CT
B-END VEL
FAILURE
SYNC
DIR TRANS SW
ONE SPEED
B-END CT
FUZE SETTER
LEFT
RIGHT
EXTERNAL
SAFE
EXTERNAL
DIRECTOR SELECTOR
SERVO ERROR TRACE
OA ERROR TRACE
SYNC PIP
OFF
LEFT
RIGHT
FUZE SETTER ENGAGED SELECTOR
NO 1
NO 2
POWER
POWER
DEMODULATOR EXTERNAL DIRECTORS
GUN MOUNT TEST PANEL
EP2 PANEL
EXTERNAL DIRECTOR
EXTERNAL DIRECTOR
DEMODULATOR NO. 1 POWER
DEMODULATOR NO. 2 POWER
B-END VEL
B-END CT
DIRECTOR TRANSFER SWITCH
POWER FAILURE (PIP)
MOUNT SYNC (PIP)
JE3
JE1
JE2
DUMMY DIRECTOR
#1
#2
POWER
INPUT
OUTPUT
PIP
POWER
INPUT
OUTPUT
PIP
LIMITER AND DEMODULATOR MODEL G
115V 60~
OSCILLOGRAPH
OSCILLOGRAPH RECORDER
ERROR/POSITION TRACE
VELOCITY TRACE

53.296
Figure 9-10. — Test equipment hookup.



THE SAMPLE ERROR TRACE SHOWN ABOVE ILLUSTRATES THE GUN FOLLOWING A 30 DEGREE AMPLITUDE/9 SECOND PERIOD ROLL SIGNAL.

THE ERROR TRACE IS CALIBRATED FOR ±5 MINUTES HALF-SCALE DEFLECTION. THE OSCILLOGRAPH IS OPERATED AT MEDIUM SPEED (0.2 SECONDS PER VERTICAL DIVISION).

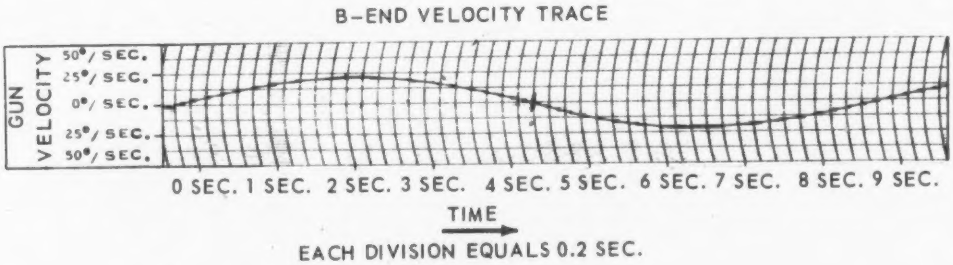
MAXIMUM ERROR OCCURS TWICE – – AT ABOUT 2.5 SECONDS AND 7 SECONDS.

ZERO ERROR OCCURS AT 0.3, 5 AND 9.5 SECONDS.

THE PIP INDICATION IS NOT PART OF THE ERROR CURVE, BUT AN INDICATION OF A SWITCH OR RELAY ACTUATION POINT.

NOTE: ALWAYS CHECK THE LEFT HAND SCALE WHEN READING ERROR TRACES.

53.297
Figure 9-11.—Sample error trace.

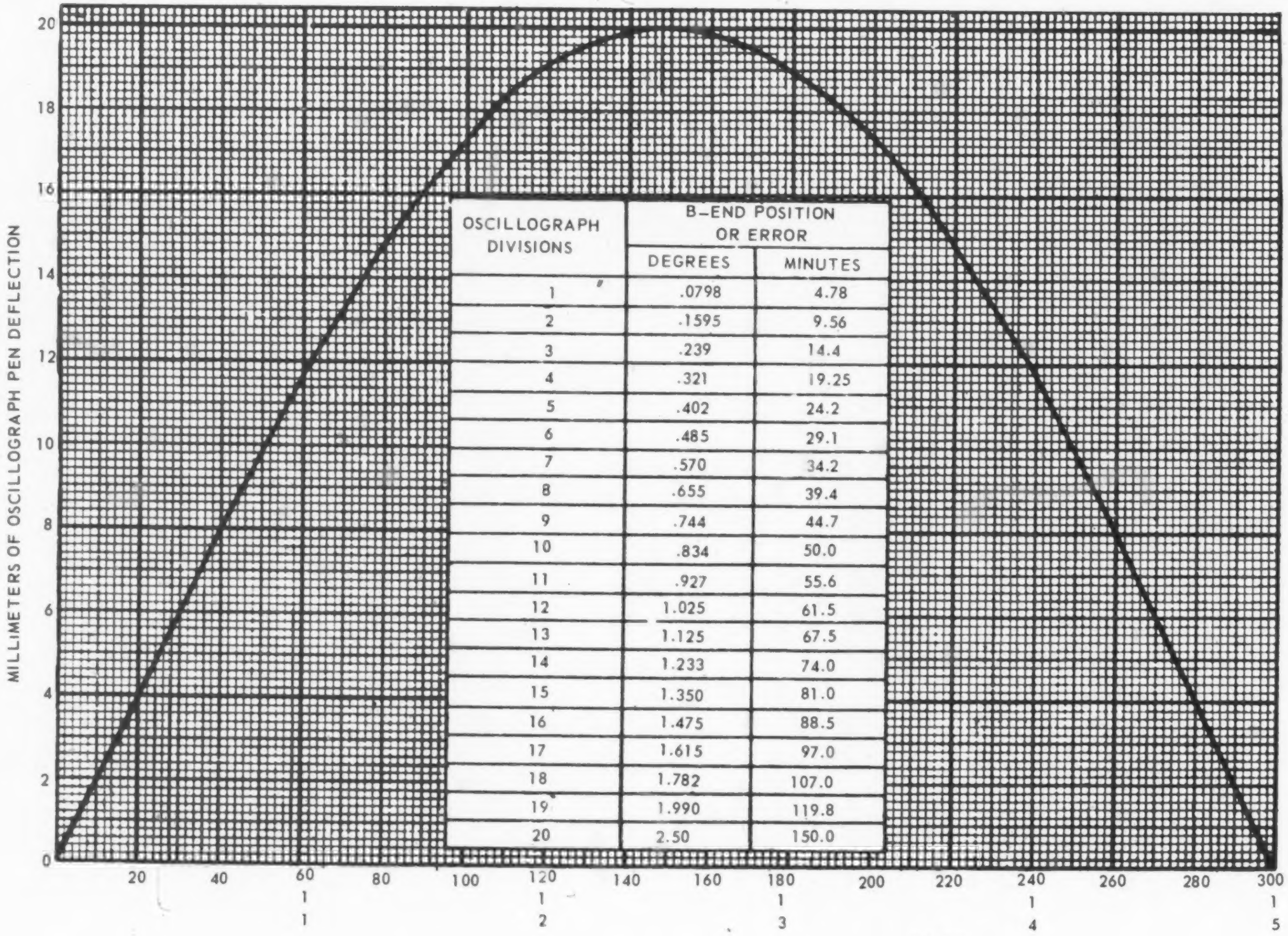


THE SAMPLE VELOCITY TRACE SHOWN ABOVE ILLUSTRATES THE GUN FOLLOWING A 30 DEGREE AMPLITUDE/9 SECOND PERIOD ROLL SIGNAL.

THE VELOCITY TRACE IS CALIBRATED FOR 50 DEGREES/SECOND FULL-SCALE DEFLECTION. THE OSCILLOGRAPH IS OPERATED AT MEDIUM SPEED (0.2 SECONDS PER VERTICAL DIVISION).

AS INDICATED ABOVE, THE GUN TRAVELS IN THE OPPOSITE DIRECTION WHEN IT CROSSES THE ZERO VELOCITY LINE. ABOVE THE ZERO VELOCITY LINE IT IS MOVING IN AN INCREASING ORDER DIRECTION. BELOW THE ZERO LINE IT IS MOVING IN A DECREASING ORDER DIRECTION.

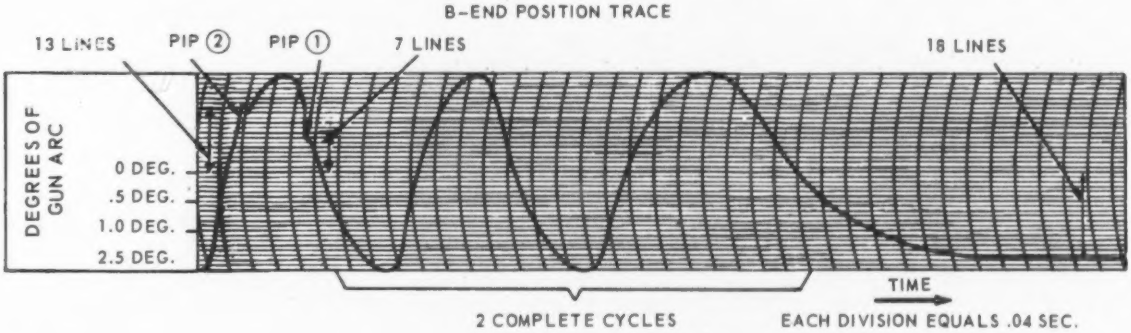
53.298
Figure 9-12.—Sample velocity trace.



OSCILLOGRAPH DIVISIONS	B-END POSITION OR ERROR	
	DEGREES	MINUTES
1	.0798	4.78
2	.1595	9.56
3	.239	14.4
4	.321	19.25
5	.402	24.2
6	.485	29.1
7	.570	34.2
8	.655	39.4
9	.744	44.7
10	.834	50.0
11	.927	55.6
12	1.025	61.5
13	1.125	67.5
14	1.233	74.0
15	1.350	81.0
16	1.475	88.5
17	1.615	97.0
18	1.782	107.0
19	1.990	119.8
20	2.50	150.0

94.55

Figure 9-13.—A. Position and error trace calibration curve.



THE SAMPLE POSITION TRACE SHOWN ILLUSTRATES THE GUN FOLLOWING A DECREASING ORDER CONSTANT VELOCITY SIGNAL.

THE POSITION TRACE IS CALIBRATED FOR ± 2.5 DEGREES FULL-SCALE DEFLECTION. THE OSCILLOGRAPH IS OPERATED AT FAST SPEED (0.04 SECONDS PER VERTICAL DIVISION). TWO PIP INDICATIONS ARE SHOWN ON THE POSITION TRACE IN ORDER TO DEMONSTRATE THE FOLLOWING:

POSITION TRACES WILL INDICATE THE AMOUNT OF GUN TRAVEL AFTER A CRITICAL SWITCH OR RELAY OPENS.

FOR EXAMPLE, GUN TRAVEL FROM THE SWITCH OR RELAY ACTUATION POINT INDICATED BY PIP ① TO ITS STOPPED POSITION IS CALCULATED IN THE FOLLOWING MANNER: AS SHOWN ABOVE, THERE ARE 7 LINES OF PEN DEFLECTION BETWEEN THE PIP INDICATION AND THE ZERO LINE. REFER TO THE LEFT SIDE OF THE CALIBRATION CURVE SHOWN IN PART A THE CURVE INDICATES THAT 7 LINES OF PEN DEFLECTION EQUAL 0.570° DEGREES OR 34.2 MINUTES. THE FOLLOWING TWO COMPLETE CYCLES EQUAL 20 DEGREES. THE PEN DEFLECTION AT THE TIME THE GUN IS STOPPED IS 18 LINES FROM THE ZERO LINE. ON THE CALIBRATION CURVE 18 LINES EQUAL 1.782 DEGREES OR 107.0 MINUTES. THUS, 0.570° + 20° + 1.782° = 22.352° (THE DISTANCE TRAVELED BY THE GUN FROM PIP ① TO THE STOPPED POSITION).

94.55

Figure 9-13.—B. Sample position trace.

deflection equals twenty lines from 0 to the edge of the trace paper 20 MM. With the demodulator attenuation switch on 5, a 5 minute signal produces 10 lines of trace deflection. At the attenuation setting of 45.75, a 2.5 degree signal produces a 20 line or full scale deflection.

Calibrate Channel #1

To calibrate the velocity trace on channel #1, select the demodulator connected to that channel (demodulator #2 figure 9-10). Set the demodulator for DC and set the oscillograph recorder chart speed for 125 MM/sec (fast speed).

Note: When the chart speed selection on the oscillograph is set at 125 MM/sec (fast speed), each vertical division of the recorder's chart paper is equal to .04 sec. When the oscillograph is set at 25 (medium speed), each vertical division is equal to 0.2 sec.

Calibrate an error trace on channel #2 so a 2.5 degree error causes full scale deflection, 20 lines. This means that one complete cycle on the error trace is equal to 10 degrees of error. The information obtained from the error trace is used to calibrate the velocity trace in the following manner.

Set up the external director to 90° train angle and the gun mount local control panel (director) to 0° train angle. Synchronize the gun mount between the external director and the local director by depressing the train external and local push button selector switch located on the gun mount test panel (figure 9-10). Select three complete cycles of error trace showing gun mount moving at maximum velocity. Multiply the three cycles by 10 for a gun movement of 30 degrees. Calculate the time for the gun to

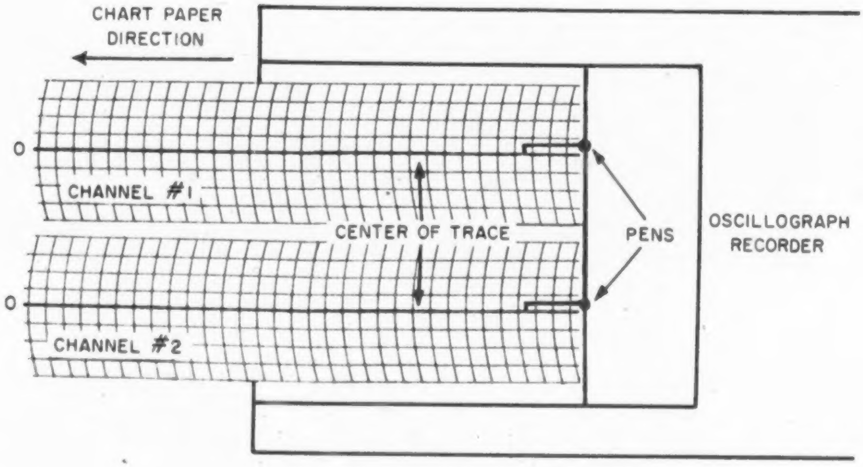
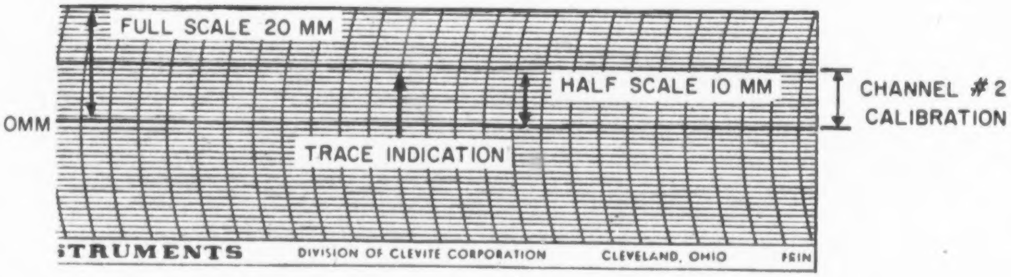


CHART PAPER DIRECTION
0
CHANNEL #1
CENTER OF TRACE
PENS
OSCILLOGRAPH RECORDER
0
CHANNEL #2

53.300
Figure 9-14.—Mechanical zero.


FULL SCALE 20 MM
HALF SCALE 10 MM
CHANNEL #2 CALIBRATION
OMM
TRACE INDICATION
TRUMENTS
DIVISION OF CLEVITE CORPORATION
CLEVELAND, OHIO

53.301
Figure 9-15.—Error/position trace.

move 30 degrees by counting the number of vertical division time lines that are within the three complete cycles. Multiply the number of time lines by 0.04. Divide 30 degrees by the time calculated. The result is maximum velocity of gun in degrees per second.

$$\frac{\text{Degrees traveled}}{\text{Time in seconds}} = \text{Velocity (degrees per second)}$$

To adjust channel #1 for velocity trace, set the chart speed for 25 MM. While the gun is moving at maximum velocity, adjust the input gain potentiometer on demodulator #2 to obtain pen deflection which represents the value calculated from the error trace. Each line of deflection from the center of the recorder's chart paper is equal to 2 1/2° per second of gun velocity. This completes the procedures for test calibration.

AMPLIFIER ALIGNMENT

Before any performance testing can be conducted on ordnance equipment, each amplifier within the system must be balanced. In the 5"/54 Mk 9 gun mounts, both the train and elevation amplifiers have adjustments which control the gain settings for gun velocity, stroke balance, and director velocity. These settings are recorded in the Shipboard Installation Test O. D. and should be checked before any amplifier alignment is conducted.

Balance Adjustments

There are three balance adjustments that can be made on most new gun system amplifiers. The purpose of these adjustments is to ensure that, when replacement parts are incorporated into a servo system such as amplifier module boards, the servo system is adjusted and aligned to the new parts. To check a system for proper amplifier alignment, tests are performed at each amplifier using the amplifier's control panel, train or elevation receiver regulator, and system test equipment. The three tests conducted are stroke balance, director velocity, and velocity potentiometer tests.

The purpose of the stroke balance adjustment is to insure that, when the gun is at 0° train and 4700' elevation, the stroke balance potentiometer stops the hydraulic B-end motion and that both the direction and magnitude of the B-end is zero. This is done by an adjustment screw for the stroke balance potentiometer located behind the front cover of both the train and elevation amplifiers. The stroke balance control potentiometer permits adjustment of the synchro reference voltage. This voltage is adjusted to correct for conditions external to the amplifier that cause undesirable displacement of the A-end tilt plate under zero error conditions.

Note: The stroke response adjustment is made at the receiver regulators to stop the B-end motion by adjusting the wiper arm of the stroke response potentiometer (SRP) with no signal from the amplifier before adjusting for director velocity.

To adjust for director velocity, set up the dummy director for a 0° train and 4700' elevation order. Place the gun mount in dummy director control and position the velocity adjustment potentiometer on the amplifier to zero (rotate the adjustment screw to the CCU stop position). Set up the dummy director for constant velocity (CV) increasing and decreasing order signals. An error and velocity trace are now required.

At the amplifier, adjust the dir-vel controls until the error trace is the same magnitude and direction from zero for both increasing and decreasing order signals. If the minimum error obtained for increasing order deflects the pen one line to the right of zero, a decreasing order should also deflect the pen one line to the right of zero.

The velocity potentiometer is adjusted at the amplifier until the B-end error is a minimum of zero with the dummy director set for a 30°, 9 second harmonic motion (SHM) signal. This completes the procedures for amplifier alignment. Shipboard performance tests may now be conducted.

READING TEST TRACES

Test traces are read like ordinary graph curves. They illustrate the error, position, or velocity of a power drive at the time the tests are made. Traces below the zero reference line are of the opposite phase from traces above the zero reference line. Be certain to check the following when reading test traces: (1) type of test being checked, (2) type of trace being used, (3) test conditions, (4) calibration of the graph, and (5) time allotted for each of the vertical graph divisions.

Keep in mind that the error and position trace voltages are generated by 36X synchros and difficulty may arise in reading test traces if the error or position readings are greater than 2.5 degrees. A gun mount movement of 2.5 degrees corresponds to a 36X synchro movement of 90 degrees. (A 36X synchro is geared to move 36 degrees for every one degree of gun movement). Since a synchro generates maximum output with a 90-degree rotor or stator displacement, the maximum trace indication occurs at an error or position displacement of 2.5 degrees. This necessitates the use of a special method to indicate error or position traces greater than 2.5 degrees.

Since a complete revolution of a 36X synchro corresponds to 10 degrees of gun movement, one complete cycle of the position or error trace corresponds to 10 degrees of gun movement. For example, if the error or position trace consists of 6 1/2 cycles, the trace will measure 65 degrees of position or trace. The 65 degrees is calculated by multiplying 10 (the degrees of gun movement per revolution of the 36X synchro) times 6.5 (the number of error or position synchro revolutions).

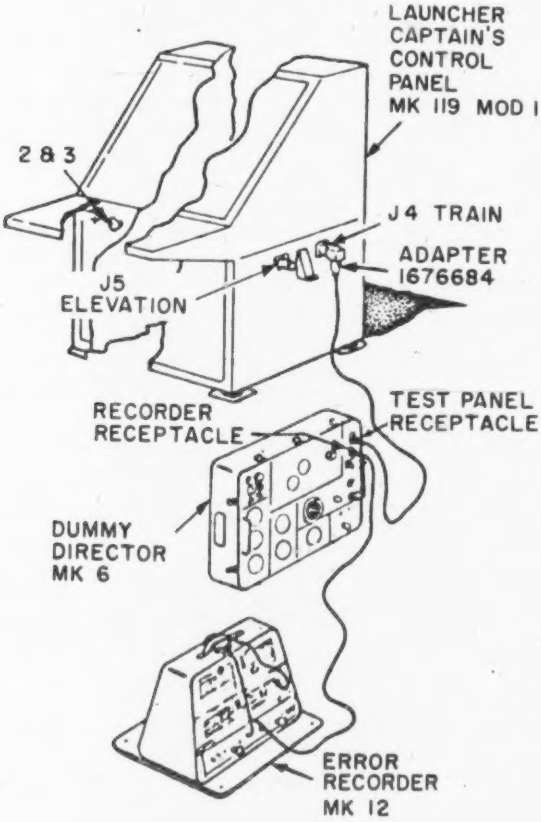
For B-end position traces of less than 5 degrees, use the calibration curve shown in figure 9-13-A to determine the exact B-end position.

Note: One feature of the oscillographs used in ordnance testing is that the chart paper is common to all equipments. For this reason the following paragraphs will explain how to interpret the test traces using the test equipment employed with the ASROC weapon system.

ASROC LAUNCHER TESTS

To conduct launcher tests, a Dummy Director Mk 6 is connected to the ASROC Launcher Captain's Control Panel and an Error Recorder Mk 12 is connected to the Dummy Director as shown in figure 9-16. Performance tests for constant velocity, simple harmonic motion, and static synchronizing are conducted.

The following paragraphs will explain how to interpret the left and right recorder chart traces. The explanations are based on a chart speed of 25 (25 millimeters per second or 5 major divisions along the centerline). For other chart speeds, different multipliers, which are proportional to the speed employed, must be used.



55.310

Figure 9-16.—Connecting the dummy director and error recorder to the 3A2 panel.

Left Channel Trace Interpretation

The left channel chart trace indicates direction, velocity, and acceleration of launcher movement. Trace deflection to the left of the centerline indicates an increasing function, either elevation of a guide or training of the launcher to the right.

With a chart speed of 25, each small division of deflection from the centerline is equal to a velocity of four degrees per second. The velocity can be determined at any instant by determining how many divisions the trace is deflected from the centerline, and multiplying the number of divisions by four. The chart can indicate a maximum velocity of 80 degrees per second (20 divisions x 4 = 80 degrees/second) on either side of the centerline with a chart speed of 25.

To find acceleration, draw a line tangent to the desired point on the trace and extend the line until it intersects both the centerline and the outside line of the chart paper. Count the number of major divisions along the centerline between the points where the tangent line intersects the centerline and the outside line. Use the following formula:

$$\text{Acceleration} = \frac{400}{\text{No. of divisions}}$$

where acceleration is degrees/second/second and 400 is a constant used when chart speed is 25 (400 = 80 divisions of maximum deflection x five major divisions per second along the centerline).

NOTE. If the trace (line) has no slope, acceleration is equal to zero.

Right Channel Trace Interpretation

The right channel chart trace indicates error, and may also be used for time measurement. Error is indicated by either a trace movement to the left or the right of the centerline during guide or launcher movement. Each small division of trace deflection is equal to two minutes of launcher error. To find the error at a point in minutes, multiply the number of small divisions that the trace has been deflected from the centerline by two minutes.

Time is measured along the centerline. Each major division along the centerline is equal to 0.2 second at a chart speed of 25. Thus, in one second, the recorder chart paper will travel five major divisions or 25 millimeters. By multiplying the number of major divisions by 0.2, the total time lapse between events can be obtained.

Examples of Recorder Chart Traces

Trace A, figure 9-17A is a typical trace of a one to two-degree, constant velocity, left train (or guide depression) test of an ASROC launcher.

The trace of the left channel parallels the centerline so that any point, such as point 1, may be selected for measurement. There is about 1/2 division deflection at point 1. Therefore, the velocity is 1/2 times four equals two degrees per second. Because the line is parallel to the centerline and has no slope, the acceleration is zero. The velocity is constant throughout the length of the illustrated trace.

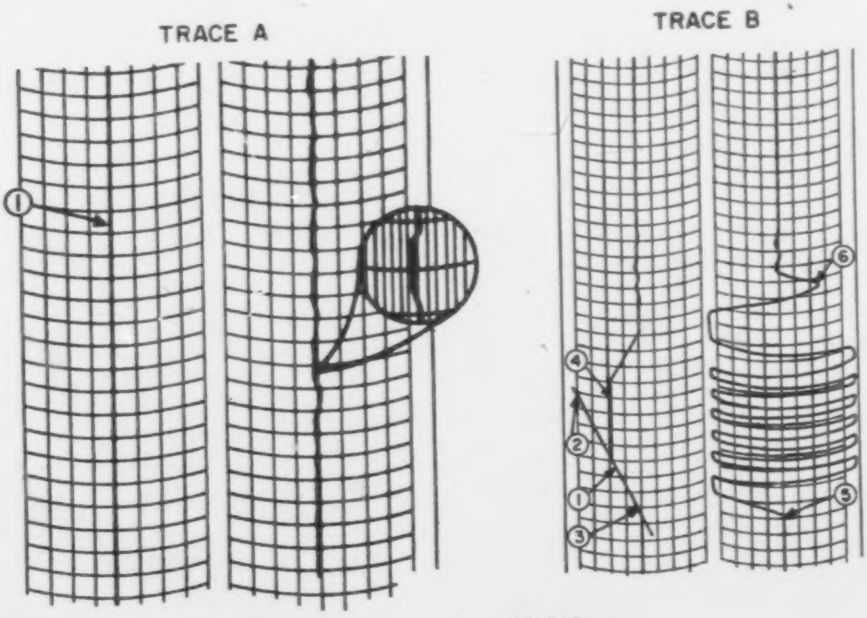
The right channel shows that the pen has moved off the centerline on both sides but not excessively. The point of maximum error (several other points are about equal in deflection) is targeted on the channel, and the small area is enlarged for better visualization. The deflection is about 1/2 division; therefore, the error is 1/2 times two equals one minute of launcher error and is well within the allowable error for this test.

Trace B, figure 9-17B is a typical trace of a launcher synchronizing 60-degree left train test.

Point 1 is the point of maximum acceleration and is usually at the midpoint of acceleration slope. By drawing a line tangent to point 1, points 2 and 3 are obtained.

Point 2 is the intersection point of the tangent line and the outside line of the chart paper.

Point 3 is the point that the tangent line intersects the centerline of the chart paper. The distance, measured along the centerline between points 2 and 3, is used to determine



53.303
Figure 9-17.—Recorder chart, typical.

acceleration. This distance is approximately seven major divisions. Use the formula:

$$\text{Acceleration} = \frac{400}{\text{No. of divisions}}$$

then acceleration is equal to 57-1/7 degrees per sec^2.

Point 4 is the maximum velocity attained and is equal to 40 degrees per second. (10 divisions x 4 degrees per division = 40).

Point 5 is the test starting point where the launcher is ordered to train left 60 degrees. Immediately, an error is recorded and, until the launcher has moved 60 degrees, the error signals are large. This is the reason for the large loops between points 5 and 6. Each complete loop (to the left, then to the right of centerline, and then back to centerline) indicates 10 degrees of launcher movement. The smaller loops at the end indicate launcher overshoot.

To find the time lapse between the start of the test and the moment when the launcher is within 20 minutes of synchronism, count the major divisions between points 5 and 6. This is equal to 14-1/2 divisions, therefore, the time lapsed is 14-1/2 times 0.2 = 2.9 seconds.

Point 6 is the point where the launcher is considered to be in synchronism when the error diminishes to 20 minutes and remains at or below this value.

Upon completion of simple harmonic performance tests, check the value against those recorded in Shipboard Installation Test ODs.

ASROC SYSTEM TEST SETS

A qualified Gunner's Mate, using the proper test equipment system maintenance procedures and reference schematics, should be able to isolate and correct any malfunction that can occur through normal usage of Relay Transmitter Mk 43 used in the ASROC weapon system. When conducting corrective maintenance of the Relay Transmitter, the first task is to determine whether the fault is in the transmitter, or somewhere else in the ASROC weapon system.

After repairing or rewiring the Relay Transmitter or associated circuits, shipboard personnel are cautioned to "cold" check the system's function circuits and perform Test Set Mk 357 checkout tests before initially applying power to the Relay Transmitter or connecting MEST test Set Mk 363. These precautions avoid damage to the test sets which could be caused by possible miswiring in the system.

Test Set Mk 357

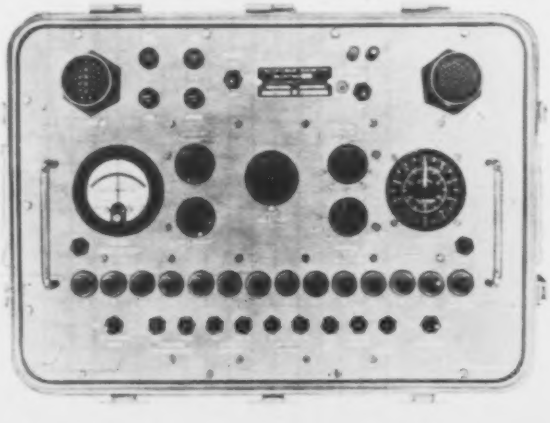
Test Set Mk 357 figure 9-18 is an electrical device used to test Relay Transmitter Mk 43 which is an electronic component of the ASROC fire control system, and is used to automatically test, monitor, and program the Ignition and Separation Assembly (ISA) of ASROC missiles.

Test Set Mk 357 is contained in a portable, spray tight case and provides an accurate method for determining if the relay transmitter is functioning satisfactorily. The test set will also indicate which module is at fault and if the relay transmitter is not operating properly. All controls, indicator, and receptacles are conveniently located on the test set front panel.

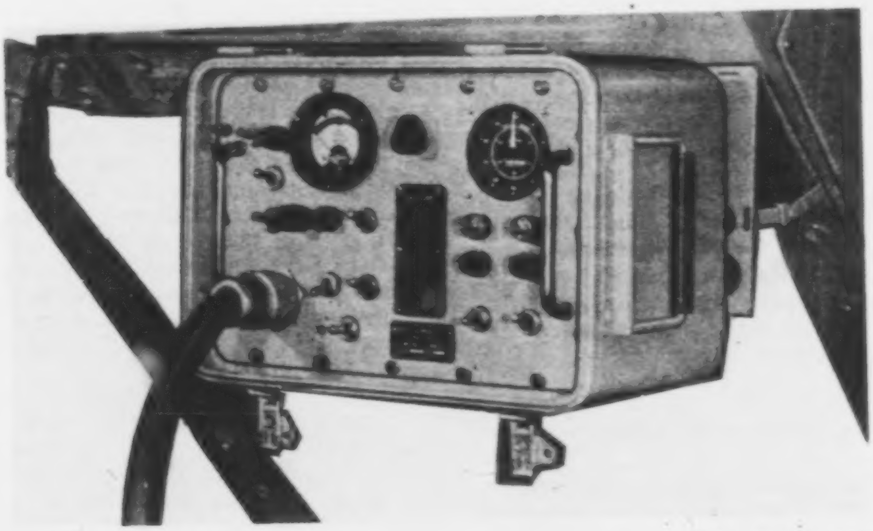
Test Set Mk 363

The Missile Electrical System Test Sets (MESTS) figure 9-19, serves two purposes: to safety test the ASROC launcher, and to simulate the electrical circuitry of a missile during tests of certain portions of the ASROC weapon system fire control.

In making the launcher safety tests, the MESTS detects either a-c or d-c voltages present in the firing circuits, and also determines by ohmmeter readings if the firing circuits are properly grounded by the Safe Fire Switch. The



15.135
Figure 9-18.—Test set Mk 357.



94.104(53C)
Figure 9-19. — MESTS Mk 363 Mod 3 - Test set mounted on ASROC launcher.

MESTS also checks for accidental grounds on the firing lines.

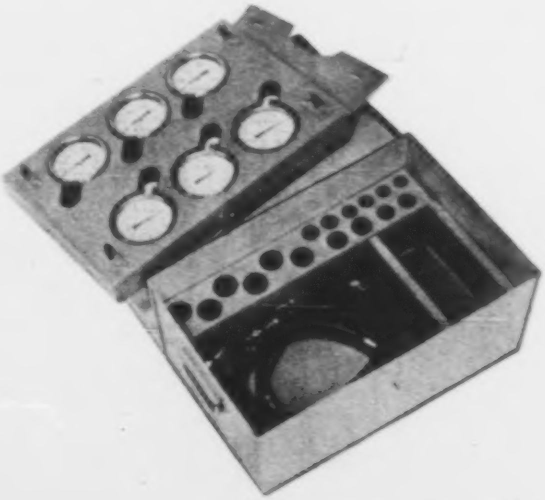
In making the missile electrical system tests, the MESTS provides:

1. Checks of the missile firing and thermal battery initiation voltages under load.
2. Continuity checks of the depth charge, torpedo, dud, and depth charge interlock indication circuitry.
3. Operational checks of the torpedo initial search depth and floor depth setting circuitry.
4. Sequence checks of thermal battery starting voltage, missile firing voltage, missile velocity at thrust cut off, and time to separation.
5. Operational checks of the fire control system set in functions.

Other information regarding ASROC Test Sets is covered in OP 2746 and OP 2981.

Miscellaneous Test Equipment

A hydraulic test kit, figure 9-20, consists of a portable metal box that contains pressure gages whose scales range from 0/100 to 0/3000 pounds per square inch (psi), a set of regulating values, a test hose, and an assortment of special adapters, pipe nipples, and couplings. This kit



53.306
Figure 9-20. — Hydraulic test kit.

is used as a pressure testing device for checking the hydraulic fluid pressures at any point within a weapon system.

An example of the kits use would be to check the servo and supercharge pressure of a hydraulic system. In the 5/54 gun system, the servo and super charge pumps produce a 400 psi and a 200 psi servo pressure, and a 100 psi transmission supercharge pressure. These pressures can be checked by removing the test plugs shown in figure 9-21 and using the proper adapters and test gages at these points to measure hydraulic pressures. The pressure tolerances vary with each hydraulic system but usually allow a difference of ±10 to ±20 psi.

DUMMY FUZE TEST GAGE

The operation of the fuze setting devices for the 5/54 gun system are checked by means of a dummy director and a dummy fuze test gage. The dummy director transmits synchro signals to the fuze setter, the fuze test gage permits comparison of position time settings between the dummy director and fuze setter.

The dummy fuze test gage consists of a dummy fuze, a dial, and a vernier index. The dial is calibrated in seconds to agree with the fuze settings; the vernier index permits readings of fuze settings to 0.01 second.

SAFETY

There has been much material written on this subject. Safety precautions are listed in many publications such as United States Navy Ordnance Safety Precautions, NAVWEPS OP 3347, and the various equipment OPs. It is up to you to familiarize yourself with these regulations. Safety precautions found in OPs and posted on the mounts must be followed strictly, of course, but in general they apply to the operating procedures of the equipment. In unforeseen circumstances you must use your own ability and initiative to prevent accidents. For this reason it would be well for you to review a few of the basic causes of accidents.

INEXPERIENCE can be the cause of accidents regardless of how careful we tend to be. The best solution to this problem is NEVER GUESS. You must learn to ask questions about equipment you are not familiar with. Work into a job gradually, and be certain of the correct procedures.

OVERCONFIDENCE can come to young and old alike, usually being associated with inexperience. Often, however, men grow overconfident when they become thoroughly familiar with a particular job. Briefly you must be confident that you know a job; but beware of overconfidence, because it invites mistakes.

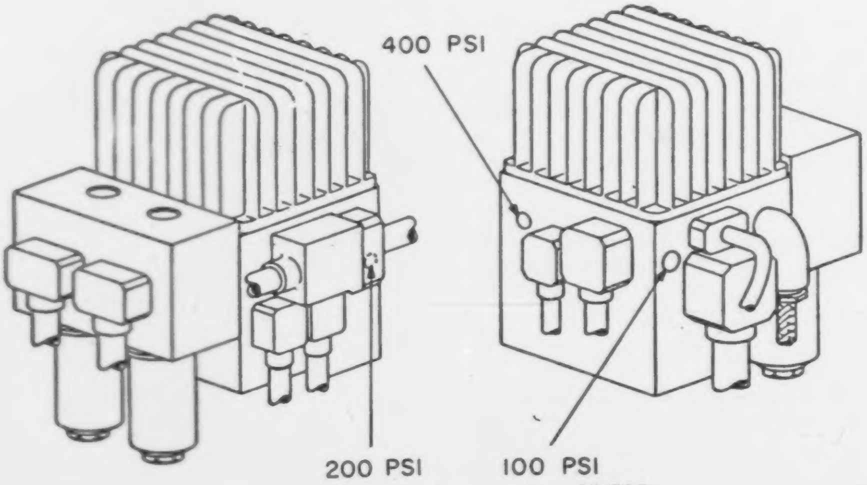


Figure 9-21. — Hydraulic test points.

CARELESSNESS is human failing which we must all overcome. It is restricted to neither the eager beginners nor the experienced technicians. Carelessness can best be combatted by including safety in GOOD WORKING HABITS. Some pointers are listed below.

1. You should gather as much information as possible on unfamiliar equipment before working on it.

2. Don't place tools where they can be accidentally dislodged into your work.

3. Use insulated tools, if they are available; otherwise wrap friction tape around those you have.

4. If power has been secured while working on a circuit, tag the circuit at the place where it was deenergized (fuze box, circuit breaker, etc.). Information on this tag should include the name of the person who had the circuit secured, and for what reason.

5. Don't take another's word that a circuit has been secured. Test it yourself. This is especially applicable when continuing a job started by someone else.

6. Attempt to keep one hand free when working with high voltage, and especially if working on the inside of a unit. This will prevent current from flowing across your body if you should accidently come into contact with a hot wire. Place an insulating rubber mat on the deck to stand on whenever working on electrically energized equipment.

7. Gather all tools and reference data necessary to complete a job before starting it. Sending a striker for an OP during the actual work not only wastes time but prevents him from learning.

8. Handle your meters with care. Using them as stepladders or miniature workbenches is likely to result in their damage.

9. Never bypass safety interlock linkages or switches. If you do, casualties to both equipment and personnel may result.

10. Establish good communications between the mount and its remote control station, such as the director, when the mount is going to be controlled by that station. This is to alert personnel at the mount to any possible danger.

11. Always ensure that no live ordnance is present before working on equipment.

CHAPTER 10

FUZE-SETTING DEVICES

Although VT proximity type fuzes have largely replaced mechanical time fuzes for primary use against AA targets, the latter are still far from obsolete. Mechanical time fuzes (MTs) still have a few important uses, such as for AA barrage purposes, for illuminating and window projectiles, and as a backup for the VT fuzed projectiles.

This chapter is written to broaden your knowledge of the devices that are currently being used in the fleet to rapidly, accurately, and automatically set mechanical time fuzes. Fuze-setting equipment as installed in the 5''/38 twin mount and in the 5''/54 mount Mk 42 will be described here in some detail as typical examples.

FUZE-SETTING EQUIPMENT FOR THE 5''/38 TWIN MOUNT

The fuze-setting mechanism for the 5''/38 twin mount consists of (1) a fuze-setting indicator-regulator, (2) fuze-setting chains, and (3) projectile flights. These three components, shown schematically in figure 10-1, will be called a regulator, fuze chains, and flights in the following discussion.

A regulator sets the fuze by controlling the position of the fuze chains. The fuze chains are endless chains mounted on the outboard side of the hoist chain (fig. 10-1) and are driven by the regulator. The flights (sometimes called fuze-pots) are secured to the hoist chain, spaced equally one from the other. The hoist chain reverses direction with each cycle; therefore, when one flight goes up, the other comes down. The flights not only support and hoist the projectile, but set the fuze as well. How this is accomplished will be explained in the following paragraphs as we study the three main components of the 5''/38 fuze-setting equipment in a little more detail.

FLIGHTS, OR SOCKETS

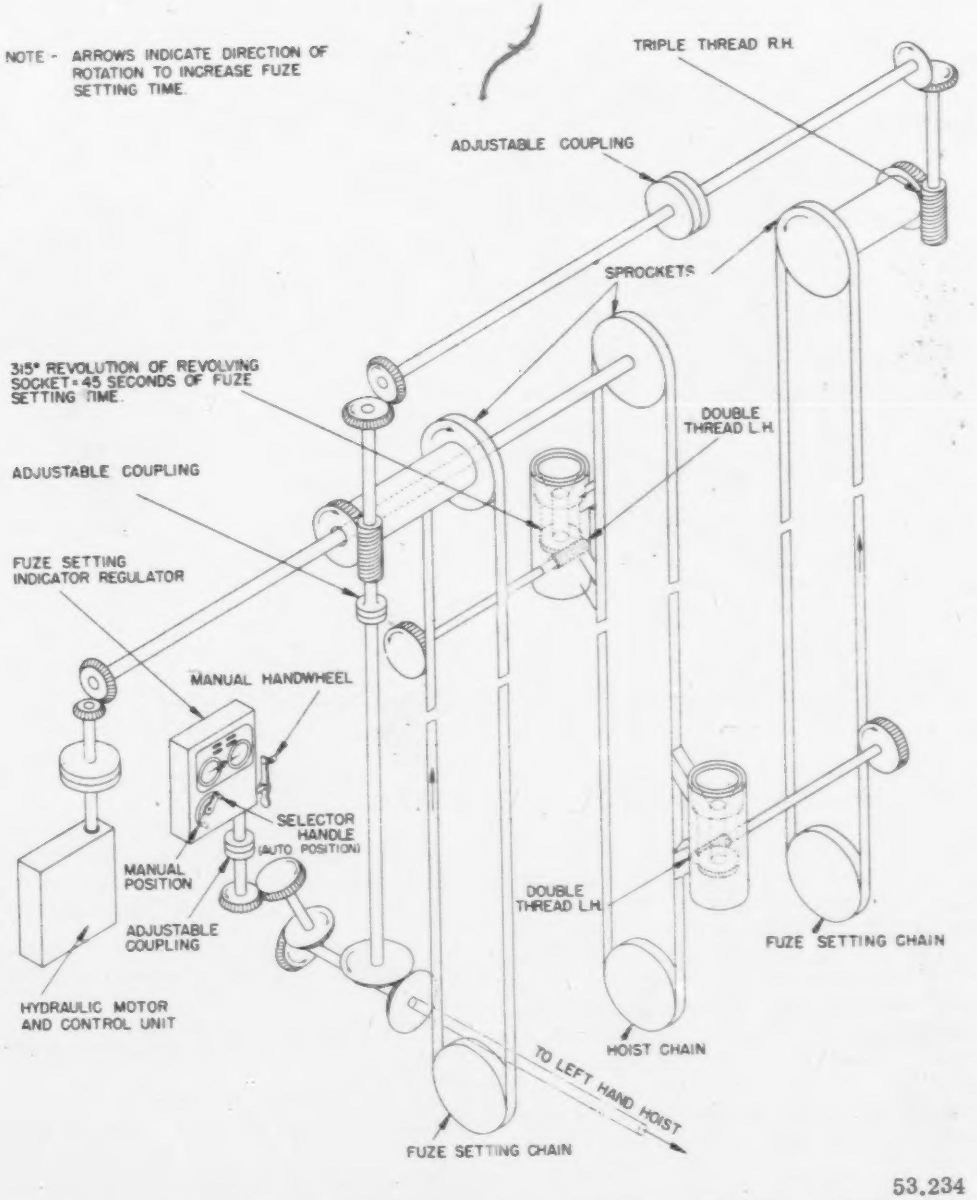
Each flight (fig. 10-2A) consists essentially of an outer socket, which is attached to the hoist chain, and an inner socket so mounted on ball bearings that it can rotate within the outer socket. The inner socket is geared to a sprocket which engages the fuze chain. Thus any movement of the fuze chain will cause the inner socket to rotate. Also, movement of the flight, itself, as it is being hoisted by the hoist chain (or lowered), will cause the inner socket to rotate as the sprocket ''walks'' up the fuze chain.

Set into the upper part of the inner socket are two spring-loaded pawls. In the top of the outer socket is a V-shaped slot. The V-shaped slot does not rotate but the spring-loaded pawls, being part of the inner socket, rotate with the inner socket whenever either the flight is moved by the hoist chain, or the fuze chain is moved by the regulator.

FUZE CHAINS

In figure 10-1, the fuze chains are schematically drawn to appear wide apart to make it easier to read the sketch. Actually, the two fuze chains and the hoist chain are very close together, as is shown in figure 10-2A. The hoist chain is driven by the hoist hydraulic power drive. The fuze chains are driven by the regulator. The regulator can be actuated either by transmitted data from the fire control system (in AUTOMATIC) or (in LOCAL) by a handcrank.

As can be seen in figure 10-1, each fuze chain is geared to and serves but a single flight. (It should be pointed out here that figure 10-1 portrays but one of the two hoists actually used in the twin 5''/38 mount. The fuze chain arrangement is identical for each of the two hoists and is driven in unison by the same regulator. Each of the hoist chains, however, is driven by its own individual hydraulic power drive unit.)

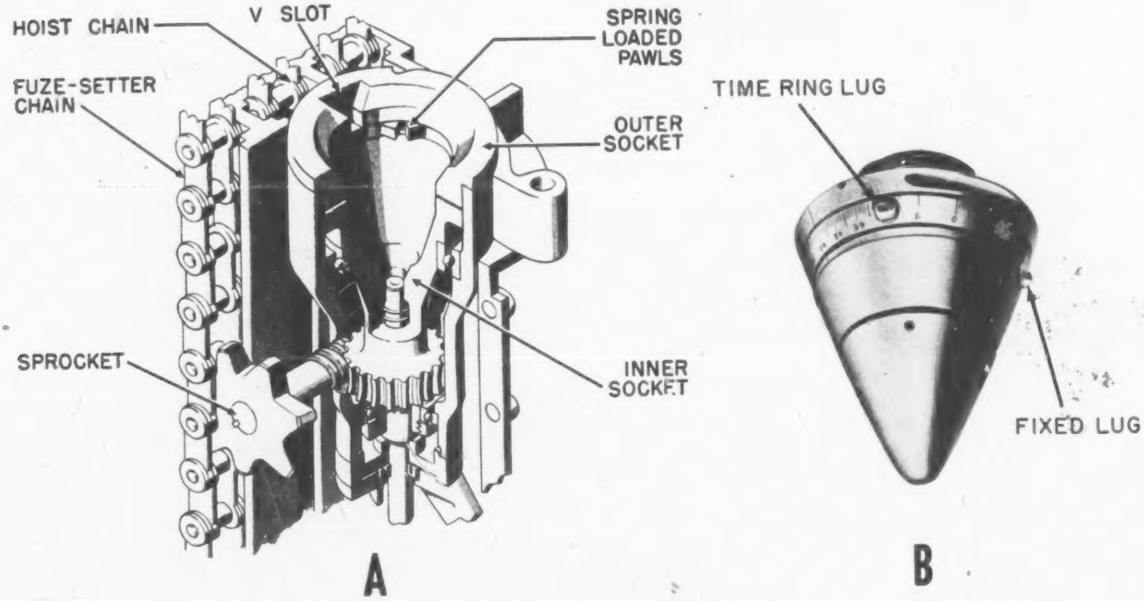

NOTE - ARROWS INDICATE DIRECTION OF ROTATION TO INCREASE FUZE SETTING TIME.
TRIPLE THREAD R.H.
ADJUSTABLE COUPLING
SPROCKETS
315° REVOLUTION OF REVOLVING SOCKET = 45 SECONDS OF FUZE SETTING TIME.
DOUBLE THREAD L.H.
ADJUSTABLE COUPLING
FUZE SETTING INDICATOR REGULATOR
MANUAL HANDWHEEL
SELECTOR HANDLE (AUTO POSITION)
MANUAL POSITION
ADJUSTABLE COUPLING
DOUBLE THREAD L.H.
FUZE SETTING CHAIN
HYDRAULIC MOTOR AND CONTROL UNIT
HOIST CHAIN
TO LEFT HAND HOIST
FUZE SETTING CHAIN

53.234

Figure 10-1. — 5''/38 projectile hoist. Hoisting and fuze-setting gear. (Schematic.)

SETTING THE FUZE

A fuze is set by rotating the time ring lug (fig. 10-2B). In operation, the projectile is put into the flight at the bottom of the hoist so that the fixed lug on the fuze goes into the V-shaped slot. The pawls in the inner socket are then in the same plane as the fuze's time ring. When the flight begins to go up with the hoist chain, the fuze chains, which are moved only by the regulator, do not move with it. The sprocket engaging the fuze chain therefore rotates as it "walks" up the chain, turning the inner socket. At some point in the flight's upward travel,



84.15
Figure 10-2.— Fuze-setting mechanism, 5''/38 caliber gun. A. Projectile flight. B. Fuze.

depending on the setting at the regulator, the spring-loaded pawls in the inner socket will have turned far enough to engage the lug on the fuze time ring. As the flight continues on up the hoist, the fuze time ring will be turned along with the spring-loaded pawls. The mechanism is so adjusted that, upon arrival at the top, the fuze is set in accordance with fuze setting order at the regulator. Should the projectile not be removed immediately, all changes in fuze setting order will continue to be set into the fuze as the regulator moves the fuze chains accordingly.

Now that we've seen the results of the regulator's output, let's take a closer look at the regulator itself.

FUZE-SETTING INDICATOR-REGULATOR MK 9

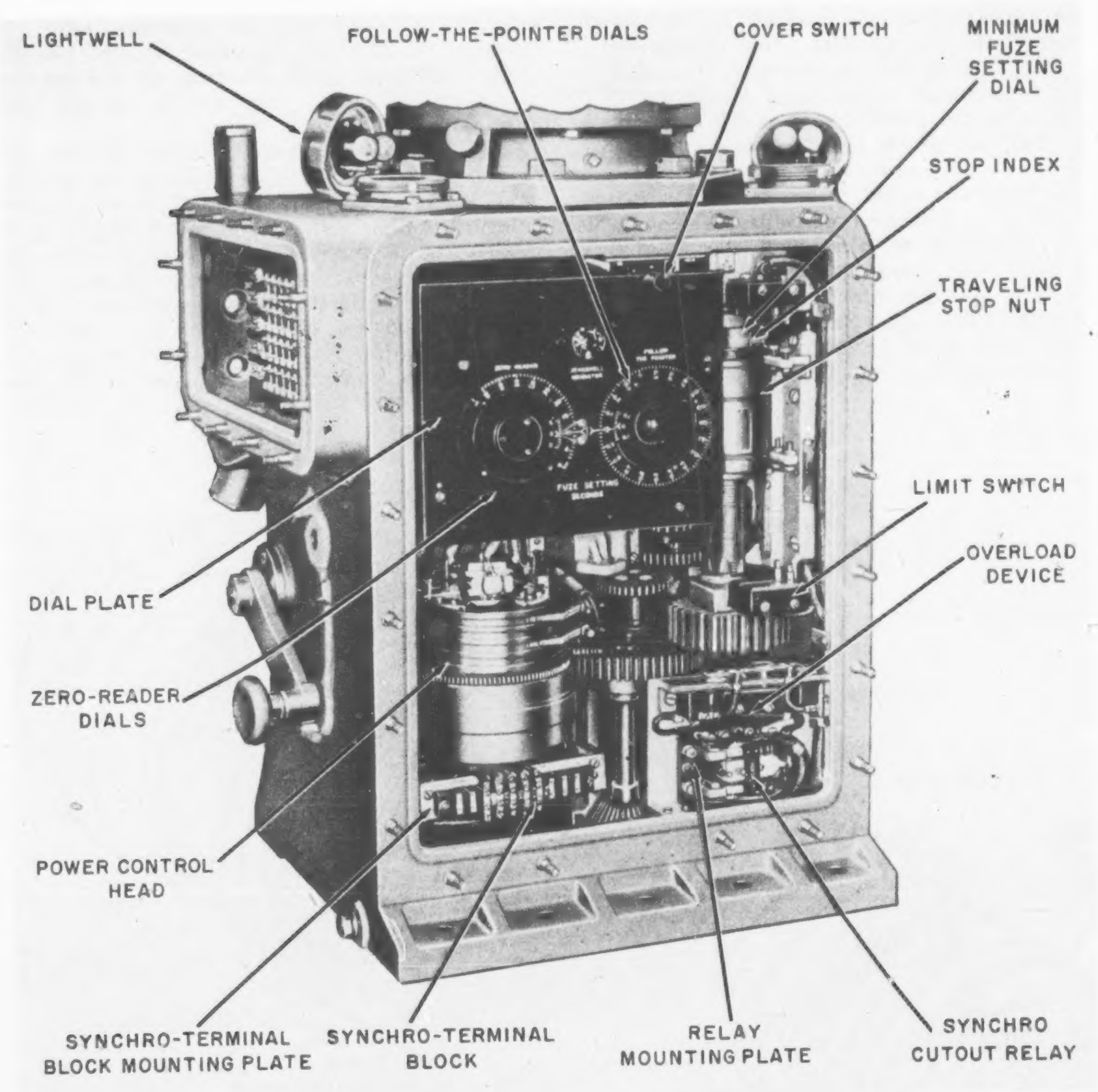
The Mk 9 Regulator is an assembly of dials, electric motors, and gearing (fig. 10-3) that receives electrical fuze setting orders from the computer and transmits those orders mechanically to the fuze-setting mechanism of the projectile hoist. The regulator can be set for either manual or automatic control by means of a selector lever.

In manual control, the gun crew fuze setter operator turns the manual handwheel to actuate the chain-setting drive, and the time setting is effected by one of the following methods:

1. By matching pointers, in which case the fuze setter operator matches pointers on two sets of regulator dials, one set of which is actuated by electrical signals from the computer, and the other set by rotation of the manual handwheel.
2. By setting the desired fuze time on the regulator dials, in which case the manual handwheel is turned until the dials indicate the desired fuze time opposite fixed index marks. This method is used when indicating signals are not available from the computer.

In automatic control, the manual handwheel is disengaged, and the fuze chains are automatically positioned by an electric power drive in the regulator. This power drive is controlled by electrical signals from the computer.

To learn more about its inner workings, we'll now study the more important components of the regulator in separate grouping.


LIGHTWELL
FOLLOW-THE-POINTER DIALS
COVER SWITCH
MINIMUM FUZE SETTING DIAL
STOP INDEX
TRAVELING STOP NUT
LIMIT SWITCH
OVERLOAD DEVICE
DIAL PLATE
ZERO-READER DIALS
POWER CONTROL HEAD
SYNCHRO-TERMINAL BLOCK MOUNTING PLATE
SYNCHRO-TERMINAL BLOCK
RELAY MOUNTING PLATE
SYNCHRO CUTOUT RELAY

53.235

Figure 10-3.—Fuze setting indicator-regulator Mk 9 Mod 0. Right front view. Covers removed.

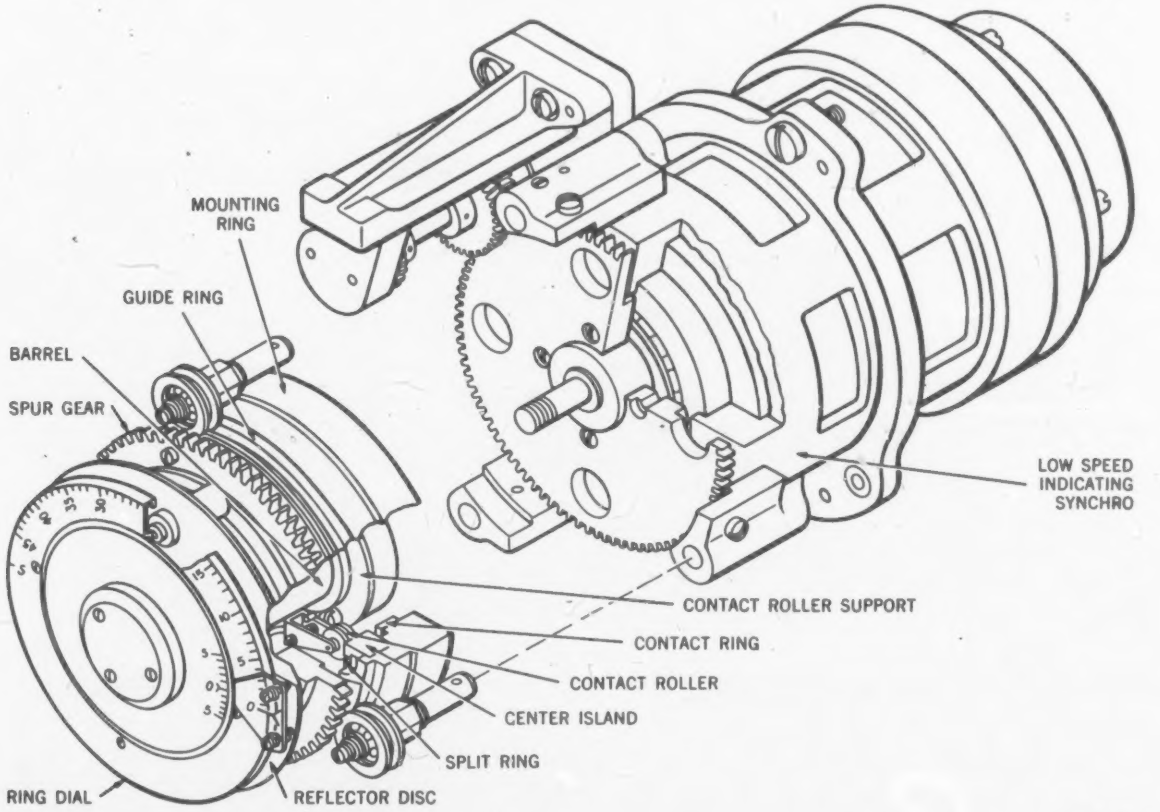
Indicating Section

The indicating section consists of a high-speed indicating synchro, a low-speed indicating synchro, and the indicating dials. The high-speed indicating synchro receives fuze-setting orders at 180/7 speed. One revolution of the synchro rotor corresponds to two seconds of fuze time. The synchro rotor is attached to the follow-the-pointer inner dial while the stator has a fixed mounting. This synchro is used for indicating purposes only.

The low-speed indicating synchro receives fuze setting orders at 3.6/7 speed. One revolution of the synchro rotor corresponds to 100 seconds of fuze time. The synchro rotor is attached to the inner dial of the zero-reader. The synchro stator is mounted on bearings and is driven by response at the same speed as the zero-reader ring dial, which is also driven by response. When the rotor is rotated by a signal, the rotation of the stator by the response to that signal will be in a direction opposite to that of the rotor. It should be noted that the rotation of the stator will cause the rotor to follow this motion so that the inner, as well as the outer, zero-reader dial will rotate.

The low-speed indicating synchro is used for both indicating and control purposes. This is made possible by the addition of a low-speed followup head (fig. 10-4) which, under certain conditions which will be explained later, can control the fuze setting power motor. The low-speed followup head consists of two principal units: a mounting ring and a contact roller assembly.

The mounting ring is made of insulating material and is fixed in position. On its inner surface it supports two contact rings. The lower ring is continuous, but the upper ring is divided into three segments separated from each other by small spaces. Two of these segments called the split ring, cover nearly the entire circle; the third, called the center island, is only a few degrees wide. Four terminals, on the outer edge of the mounting ring, connect the lower



53.236

Figure 10-4.—Low-speed indicating synchro and follow-up head for fuze setting indicator regulator Mk 9.

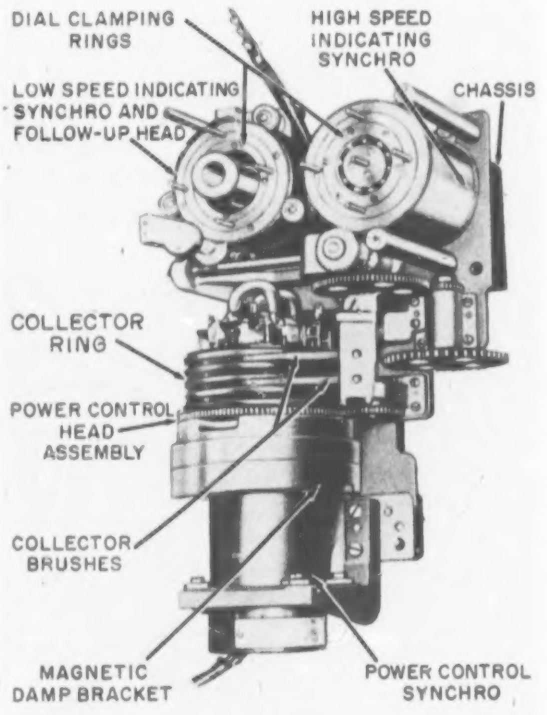
contact ring and the three segments of the upper contact ring to the external circuits.

The contact roller assembly is mounted on, and rotates with, an insulating extension of the rotor shaft of the low-speed indicating synchro. It has two contact rollers, mounted on flexible arms, which are spring extended to hold the rollers firmly in contact with the rings. Flexible wire shunts assure good connections between the main body of the assembly and the arms that carry the rollers. One of the rollers makes contact with the continuous lower ring; the other makes contact with the segmented upper ring. The particular segment that it contacts depends upon the relative positions of the synchro rotor (fuze setting order) and the zero-reader dial (existing fuze setting). When a roller is in contact with either segment of the split ring, it causes the power motor controller to energize the power motor. When the roller rests on the center island, which occurs when the difference between order and existing setting is small, it permits the power control head to energize the power motor. In each case the circuit within the head is from the continuous ring, through the roller assembly, and then to one of the segments of the split ring or to the center island.

Power Control Synchro and Power Control Head

The power control synchro and power control head (fig. 10-5) control the action of the power motor only when the difference between fuze setting order and existing fuze setting is small. The power control synchro rotates at the same speed 180/7, as the high-speed indicating synchro, and receives its stator signal from the same source. The rotor is energized with 115-volts from a step-down transformer. One revolution of the power control synchro corresponds to two seconds of fuze time.

The power control head (fig. 10-6) compares fuze setting order, as received by the power control synchro, with existing fuze setting, which is received automatically through response gearing from the power motor. It acts, through the power motor controller, to cause the power motor to run in the direction necessary to set the fuze in accordance with the order. It also acts, through the controller, to cause the motor to operate at high or low torque, depending on the magnitude of the difference between order and existing setting.


DIAL CLAMPING RINGS
HIGH SPEED INDICATING SYNCHRO
CHASSIS
LOW SPEED INDICATING SYNCHRO AND FOLLOW-UP HEAD
COLLECTOR RING
POWER CONTROL HEAD ASSEMBLY
COLLECTOR BRUSHES
MAGNETIC DAMP BRACKET
POWER CONTROL SYNCHRO

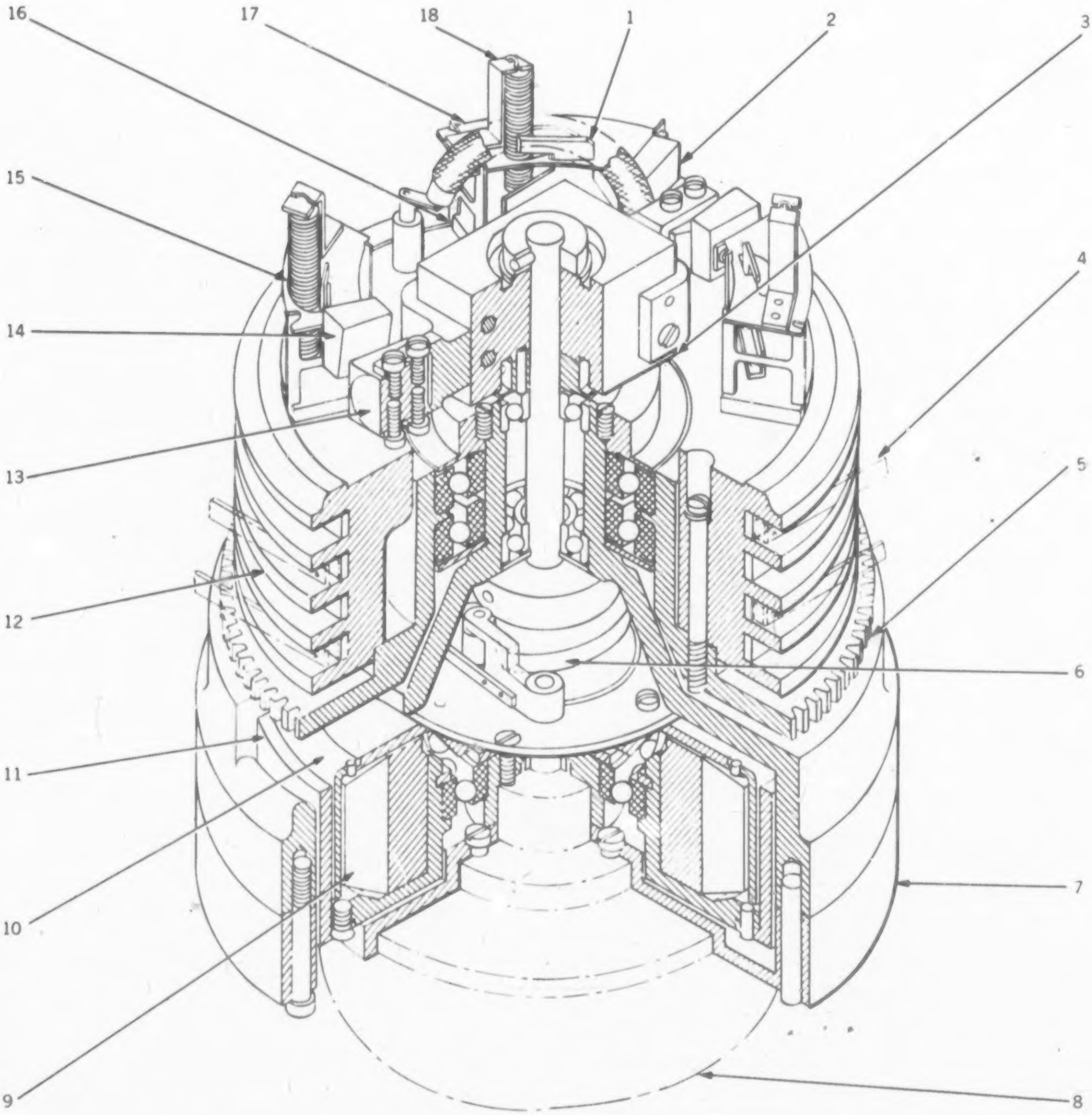
53.237

Figure 10-5.—Fuze setting indicator-regulator Mk 9 chassis assembly.

The power control head consists of five groups of parts, arranged so that they can rotate with respect to each other or with respect to the synchro housing. These groups are as follows:

Magnetic damp assembly
Driving cam assembly
Collector ring assembly and response input gear
Outer contacts and supports
Inner contacts and supports

MAGNETIC DAMP ASSEMBLY.—One part of the magnetic damp consists of a circular permanent magnet and support mounted on ball bearings so that they are free to rotate independently of the synchro housing and of all the other units of the followup head. A copper drum, mounted on the driving cam assembly (fig. 10-7),

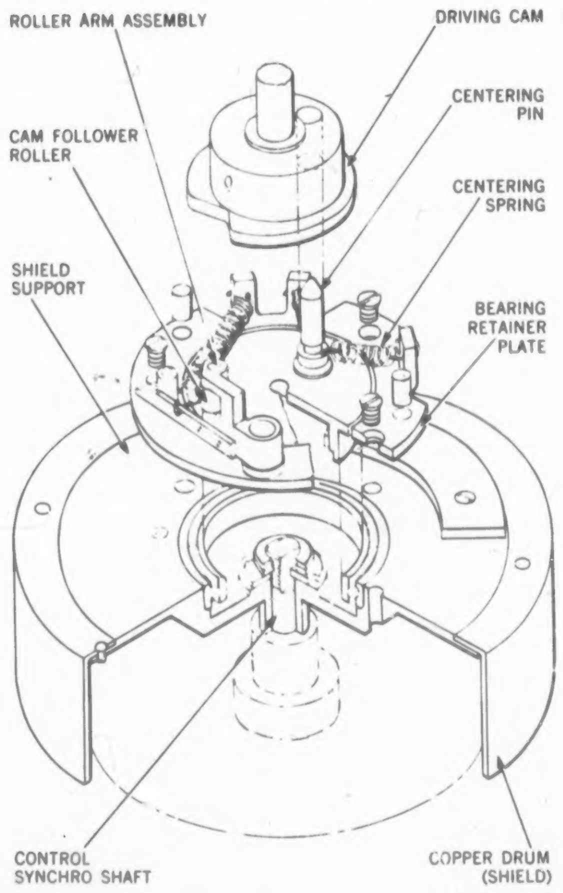


LEGEND

1-STOP
2-OUTER CONTACT
3-INNER CONTACT SUPPORT
4-BRUSH
5-RESPONSE INPUT GEAR
6-DRIVING CAM ASSEMBLY
7-MOUNTING BRACKET
8-CONTROL SYNCHRO
9-MAGNET
10-COPPER DRUM (SHIELD)
11-FIELD RING
12-COLLECTOR RING ASSEMBLY
13-INNER CONTACT
14-OUTER CONTACT
15-CONTACT SUPPORT SPRING
16-H-SHAPED SPRING PLATE
17-OUTER CONTACT SUPPORT
18-VERTICAL ARM

53.238

Figure 10-6.—Power control head.



53.239
Figure 10-7.—Driving cam assembly. Exploded view.

forms the other member of the damp. The driving cam assembly is secured to the synchro rotor, and the copper drum therefore rotates with the synchro shaft. Drum rotation sets up eddy currents that tend to cause rotation of the magnet. The inertia of the magnet keeps it rotating after shaft rotation has ceased and the induced currents create a torque that tends to carry the drum along with the magnet. The result is a flywheel action that produces smoother operation.

DRIVING CAM ASSEMBLY.—The driving cam assembly (fig. 10-7) permits the inner and outer contacts to come together without shock. It does this by providing a temporary and controlled amount of lost motion between the synchro shaft and the inner contacts, which are positioned by the synchro shaft. As shown in figure 10-7, the driving cam is mounted on a centering pin which, in turn, is mounted on an inner plate that is free to rotate with respect to the synchro shaft. The centering pin is attached by two springs to lugs on the bearing retainer plate, which is screwed to the shield support and therefore rotates with the synchro shaft. A roller arm assembly also is mounted on the bearing retainer plate with a spring that holds its roller normally in the bottom of the cam notch.

The cam has a shaft extending upward to carry the inner contacts as shown in figure 10-6. At the start of movement, when a signal is first received, the centering-pin springs cause the cam to rotate with synchro shaft. However, as soon as an inner contact meets an outer contact, the cam tends to resist further rotation until response speed overtakes synchro shaft speed. During this interval, one centering spring is compressed and the other is extended. At the same time, the cam follower roller is driven up one side or the other of the cam notch. When the synchro and response speed become equal, or when the setting becomes matched to a stationary signal, the centering springs return the cam to normal position where it is exactly centered by the cam follower returning to the bottom of the cam notch.

COLLECTOR RING ASSEMBLY AND RESPONSE INPUT GEAR.—The collector ring assembly, shown in figure 10-6, is the unit through which connections are made from the rotating power control head to the power motor controller. (The power motor controller is mounted down in the ammunition handling room). It is mounted on, and secured to, the response input gear and carries, on its upper surface, a set of four outer contacts. The response input gear receives its drive from the output of the power motor so the position of all these units is directly proportional to existing fuze setting.

Four collector rings are mounted in channels in the outer surface of the insulating body of the assembly. These rings are connected by means of brushes to the circuit of the power motor controller, so that uninterrupted continuity is maintained regardless of rotation. The rings are connected internally to terminals in the upper surface of the body for connection to the contacts described below.

OUTER CONTACTS AND SUPPORTS.—Four outer contacts are mounted on flexible supports on the upper surface of the collector ring. These contacts are connected in two pairs: each pair is connected to a slip ring. The flexible mounting permits some displacement of the outer contacts by the inner contacts.

INNER CONTACTS AND SUPPORTS.—The inner contacts are mounted on a support that is positioned by the driving cam shaft. Its position is therefore indirectly determined by synchro shaft position. There are two inner contacts, insulated from each other and from the shaft by the support. They are connected, through flexible leads, to the remaining two collector rings. Since there is never more than a few degrees of difference between the positions of the collector ring assembly and of the inner contacts, the flexible leads provide sufficient freedom of movement.

Principle of Operation of Power Control Head

The power control head, as shown in figure 10-8, employs six contacts connected so that there are four points of electrical connection. Inner contacts 1 and 3 have a common support and are rotated together by the control synchro. It should be kept in mind, however, when studying these diagrams, that contacts 1 and 3 are not electrically connected to each other. Contacts 2A, 2B, 4A, and 4B are rotated together by the response of the power motor. They always rotate in such a direction as to follow contacts 1 and 3, and therefore the signal. Thus the power control head is an error-detecting device that compares the signal with the existing fuze setting.

LOW TORQUE OPERATION.—Through use of the power control head, two steps of torque (low and high) are available. Figure 10-9 shows the circuit conditions with a signal for clockwise rotation and where low torque only is required to follow within the limits of the contact setting. Under these conditions, contacts 1 and 2B are closed. Closing the contacts energizes the power motor by putting line voltage across T2-T3 of the stator and energizes the T1 leg of the motor through condenser C. The motor is thus connected across only one phase of the power supply. The effect of the condenser is to produce a time phase difference between the electric currents in the stator winding of the power motor so that a rotating magnetic field is obtained. It is the rotation of this field that causes the power motor to rotate.

A reversal of the signal demand to counterclockwise would open contacts 1 and 2B and would close contacts 3 and 2A. This connection energizes the power motor stator in a direction opposite to that shown in figure 10-9. In this type of connection T3 and T1 are energized from the power control head and T2 is energized through condenser C, with the result that the motor runs in the opposite direction.

In both the above cases, the motor operates as a capacitor start, capicator run, single-phase motor which produces sufficient torque to synchronize with the signal when the change in fuze setting required is small.

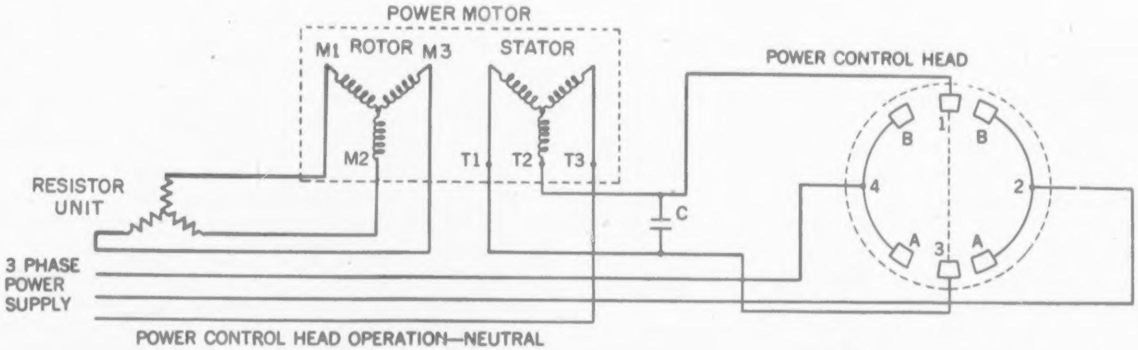


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Figure 10-8.—Power control head operation. Neutral.

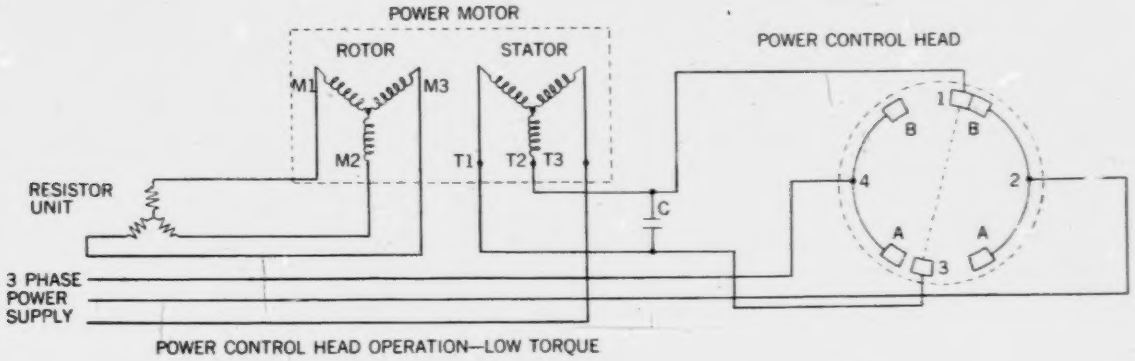

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Figure 10-9. — Power control head operation. Low torque.

HIGH-TORQUE OPERATION. — The torque required of the power motor will be greater under some conditions than that which was available under first-contact operation, as was explained above. Under such conditions, response will begin to lag behind the demand of the signal until contact 3 makes contact with contact 4A, as shown in figure 10-10. In this case the power motor is connected directly across the three-phase line and the maximum available torque of the motor is obtained. As in low-torque operation, a reversal of signal demand would reverse the line connections to T1 and T2 through the power control head which would, in turn, reverse the direction of rotation of the power motor. Condenser C remains across one phase of the power motor during three-phase operation, but has no appreciable affect on the motor operation.

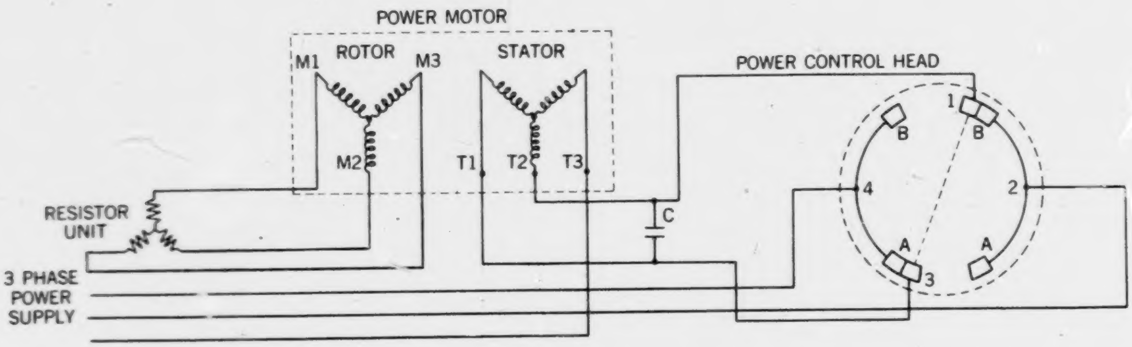
Operation of a three-phase motor from a single-phase line, as described in low-torque operation, is known as split-phase operation. The torque available under this condition of operation may be varied, within limits, to suit a particular installation by varying the value of condenser C. This will permit adjusting the low-torque operation of the system without affecting the high-torque operation. Normally, however, no adjustment is required.

Operation Under Control of the Low-Speed Indicating Synchro and Followup Head

Operation of the regulator system can be controlled through either the control synchro or the low-speed indicating synchro. As previously explained, the control synchro controls the system when the difference between fuze setting is small. In this respect, it can be compared to the fine control for the 5"/38 hydraulic power drive as described in chapter 6. Likewise, regulator control under the low-speed indicating synchro and followup head can be compared to the coarse control described in that chapter.

The low-speed synchro controls the system only when it is synchronizing to an advanced signal, or to bring the system back into synchronism when the power motor has followed the signal to the electrical limit of the limit stop mechanism. The low-speed synchro receives fuze setting order at 3.6/7 speed, whereas the control synchro receives it at 180/7 speed. As explained earlier, one revolution of the power control head is equivalent to two seconds of fuze time. If this were the only control head in the regulator, then the existing fuze setting could be apparently synchronized with the signal at any one of several values of fuze setting; which differ from the signal by multiples of two seconds. The low-speed followup head eliminates this possibility.

The low-speed indicating synchro rotor rotates the contact roller assembly of the low-speed followup head. One revolution of the contact roller is equivalent to 100 seconds of fuze time. As was noted in the description of the low-speed synchro, the stator of the low-speed synchro is rotated by response in a direction opposite to that in which the signal rotates the rotor. Since



53.242

Figure 10-10.— Power control head operation. High torque.

rotation of the stator causes the rotor to follow its motion, then any difference between the signal and the existing fuze setting will cause the rotor and the contact roller assembly to be displaced from their neutral position through an angle corresponding to the error.

The roller in the low-speed followup head normally rests on the center island. However, if the roller moves to one of the split rings, it breaks the circuit through which the synchro cutout relay and the controller cutout relay are energized. When the synchro output relay is deenergized, the stator circuit to the control synchro is broken, preventing the latter from receiving the signal. When the controller cutout relay is deenergized, it breaks the 440-volt supply to the power control head, preventing the latter from energizing the power motor. Thus, when the roller moves off the center island, control of the power motor is taken away from the power control head.

Assume now that the regulator must synchronize to an advanced signal, for example 30 seconds away, in the direction for increased fuze time. The roller of the low-speed head will no longer rest on the center island, but will rest on a split ring and will take power motor control away from the power control head, as described above. A 115-volt control circuit is now completed through the low-speed head, an increase limit switch, an increase following relay, a decrease following relay, and the controller cutout relay. The increase following relay is energized and closes the contacts that connect T1 and T2 of the power motor to the power contactor. Since T3 is permanently connected to the contactor, the power motor is connected directly across the 440-volt line and operates to overtake the signal with maximum torque. When the contact roller returns to the center island, the increase following relay is deenergized and the synchro cutout relay and the controller cutout relay are energized. The power control head thus again takes over control of the power motor.

If the signal were for decreased fuze time, the contact roller would rest on the other split ring. The decrease following relay would be energized through the decrease limit switch. The connections of terminals T1 and T2 to the power contactor would then be reversed from the connections required for increased fuze time, and the motor would rotate in the reverse direction.

Another function of the low-speed head is to bring the system back into synchronism when the power motor has followed the signal to the limit of the limit stop mechanism. Assume now that the signal has traveled beyond the lowest fuze setting time set on the limit stop mechanism. The power motor then drives the limit stop traveling nut into the decrease limit switches. The first decrease limit switch breaks the 115-volt control circuit to the synchro cutout relay and the controller cutout relay, which are then deenergized. This, in turn, deenergizes the power control head in the manner previously mentioned. The second decrease limit switch breaks the circuit from the decrease split ring of the low-speed head, which would otherwise energize the power motor. The limit stop mechanism thus acts not only as a mechanical stop, but also deenergizes the regulator for further decreasing fuze-setting signals. The limit stop mechanism itself will be further described later in the chapter.

If a signal for increasing fuze setting is now received, the power control head cannot energize the power motor because of the open limit switches. The roller of the low-speed head therefore rolls onto the increase split ring. Since the increase limit switches are closed, the power motor is energized and the limit stop traveling nut is driven away from the stop. This permits the decrease limit switches to reclose, and the power control head can then take over control of the power motor as soon as the signal is overtaken.

Limit Stop Mechanism

The limit stop mechanism is of the traveling nut type. It prevents the regulator from operating, in either automatic or manual, beyond the limits of fuze setting. When either the upper or lower limit of fuze setting has been reached, the mechanism opens a limit switch which deenergizes a relay in the power motor controller and thereby breaks the supply circuit to the power motor. It also acts as a positive stop to the transmission gearing. Figure 10-11, a schematic sketch of the regulator's components, shows the limit stop mechanism.

The traveling nut assembly of the limit stop mechanism serves as a buffer at the mechanical limits of travel in addition to providing the electrical and mechanical stopping action previously referred to. It does this by permitting some override of the driving motor and gearing while preventing this override from being transmitted to the fuze.

As figure 10-11 shows, two mechanical stops are mounted on the limit stop shaft and rotate with it. The lower stop, which is not adjustable, sets the maximum limit of fuze setting; the upper stop, which is adjustable, sets the minimum limit. A lug on the upper face of the lower stop engages a corresponding lug on the lower face of the splined sleeve when the maximum limit of fuze setting has been reached. A similar lug on the lower face of the upper stop engages a lug on the upper end of the ratchet when the minimum limit has been reached. In either case, the friction discs in the traveling stop nut assembly slip sufficiently to permit some additional rotation, thus avoiding mechanical shock and damage to the gearing, but their brake action prevents the movement from continuing too far.

In regulators of early manufacture, the limit stop mechanism permitted a maximum setting of 48.75 seconds. This limit has been increased to 50.35 seconds in the newer regulators. The lower limit in either is adjustable from 0 to 5 seconds. Check current type commander's instructions as to the minimum fuze setting limit allowable for your ship.

As figure 10-11 shows, there are two limit switches at each end of limit stop travel. Each is a single-pole, double-throw unit, wired into the circuit as single-throw, normally closed switches. One switch at one end of the limit stop is in series with one switch at the other end of the limit stop. These switches are in series with the center island of the low-speed followup head in a circuit that energizes the synchro cutout relay in the regulator and the controller cutout relay in the controller. The opening of either of these relays, when the low-speed followup head roller is on the center island, therefore deenergizes the power motor through the controller and also opens the stator circuit of the power control synchro so that it cannot receive further fuze setting signals.

Each of the other two limit switches is in series with a split ring of the low-speed followup head. The opening of one of these switches will therefore open the circuit through which the low-speed head causes the power motor to drive in the direction of the excessive signal, but will not open the circuit for the opposite direction of drive. If, therefore, an opposite signal is received, it will move the low-speed roller to the opposite split ring, and the power motor will then back the regulator out of its electrical limit automatically. This feature prevents the loss of time that would occur if it were necessary to back the regulator out of its limit by the use of manual drive.

Operating Precautions

The following precautions are important and must be rigidly observed in order to ensure safe operation of the regulator:

1. Before shifting selector to AUTO make certain that the signal is first matched in manual control, as indicated by dials. Failure to do so may result in damage to the regulator.
2. Before shifting to AUTO, make certain that there is a projectile in one of the hoists. Failure to do so may result in damage to the regulator.

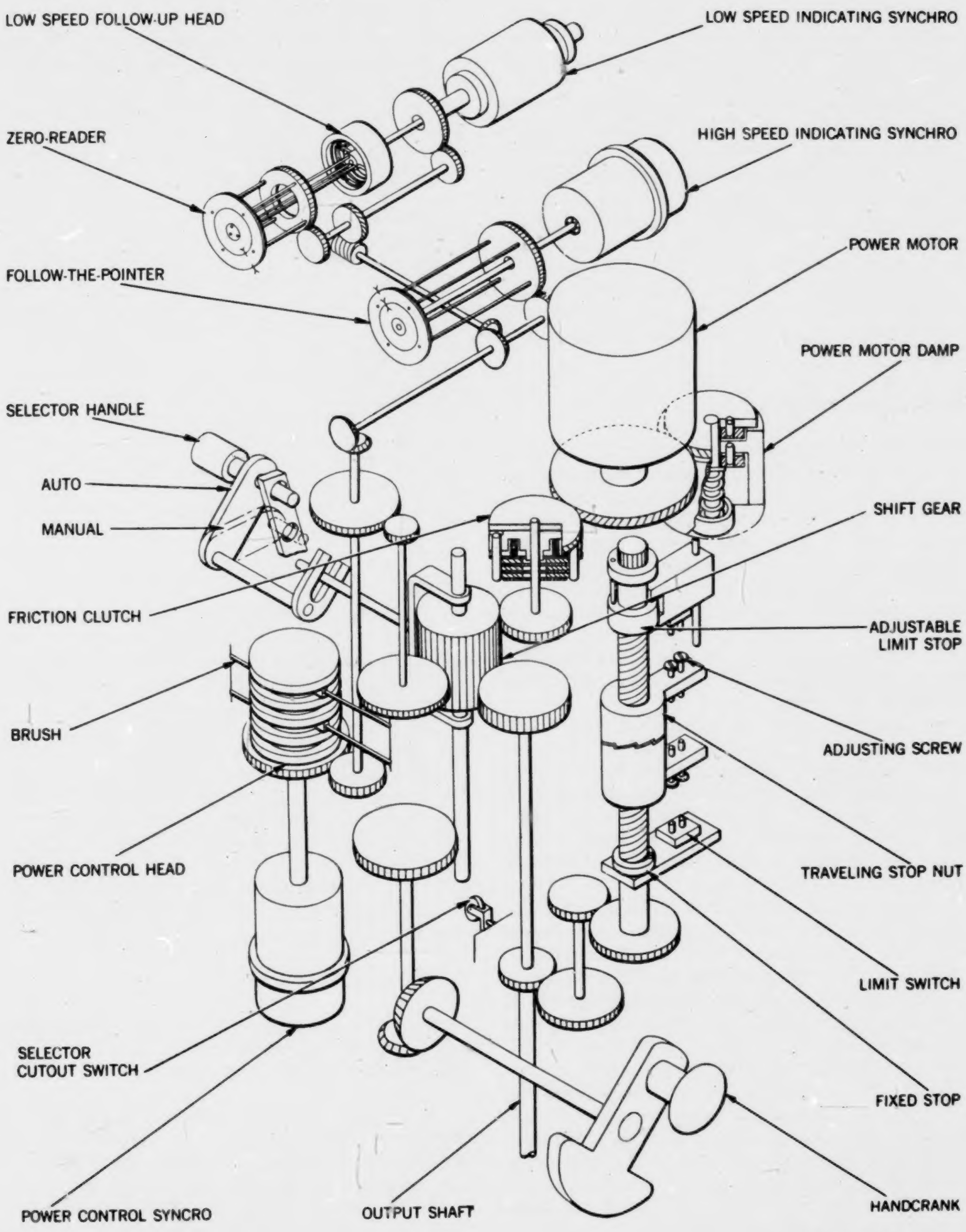

LOW SPEED FOLLOW-UP HEAD
LOW SPEED INDICATING SYNCHRO
ZERO-READER
HIGH SPEED INDICATING SYNCHRO
POWER MOTOR
FOLLOW-THE-POINTER
POWER MOTOR DAMP
SELECTOR HANDLE
AUTO
MANUAL
SHIFT GEAR
FRICTION CLUTCH
ADJUSTABLE LIMIT STOP
BRUSH
ADJUSTING SCREW
POWER CONTROL HEAD
TRAVELING STOP NUT
LIMIT SWITCH
SELECTOR CUTOUT SWITCH
FIXED STOP
POWER CONTROL SYNCRO
OUTPUT SHAFT
HANDCRANK

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Figure 10-11.—Fuze-setting indicator-regulator Mk 9. Mechanical schematic.

3. Before shifting to AUTO, make certain that the synchros are energized. If the synchros are not energized when selector is at AUTO, the center contacts of the power control head are uncontrolled and the power motor may run away causing damage to the regulator.

4. When the regulator is not in use, selector must be set at MANUAL and the power switch must be set at OFF. Failure to do so will probably result in damage because the requirements of the paragraphs above are not being met.

5. WARNING. If any work is to be done on the regulator, turn off power at the controller to avoid touching live wires.

FUZE-SETTING EQUIPMENT FOR THE 5"/54 GUN

The Mk 42 5"/54 Mod 1 thru 8 gun mount is equipped with two separate fuze-setting assemblies, mounted on the upper outboard sides of the slide as shown in figure 10-12. Fuzes are set as the projectile lies in the transfer tray by the fuze pot which, by means of an extending and retracting mechanism, is extended from the fuze setter to contact and set the projectile fuze. When the fuze has been set, the fuze pot is retracted and the projectile is automatically lowered into position for ramming and firing. The right and left fuze-setting systems operate independently, automatically, and in synchronism with the left and right transfer trays of the gun loading systems.

Each of the two fuze-setting systems includes a fuze pot extending and retracting mechanism and a fuze setter. Each fuze setter contains a fuze pot mechanism and a receiver-regulator. The fuze setting and holding pawls of the pot mechanism are positioned by control elements of the receiver-regulator. The regulator is connected electrically to a remote fuze order transmitting station and to the fuze setter amplifier in the P2 amplifier panel in the carrier room.

Each of these major components of the fuze-setting system will be described in this chapter, along with their function in the system and operational characteristics. Although the equipment to be described here is, in most respects, quite different from that of the 5"/38, certain similarities can be noted between the two systems. Look for these as you study this part of the chapter.

FUZE POT EXTENDING AND RETRACTING MECHANISM

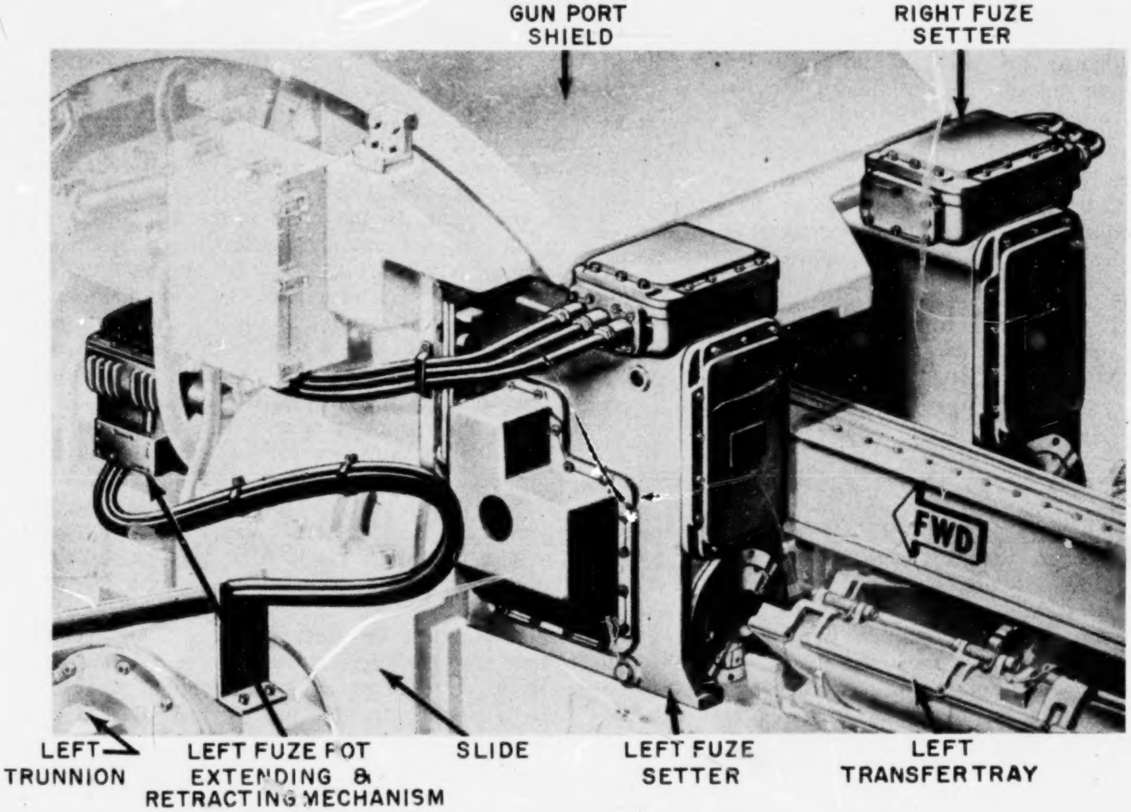
You will recall that fuzes were set in the 5"/38 gun mount while the projectile was in the projectile hoist. The fuze pot was included as an intergral part of the hoist flight and thus the projectile fuze remained in full contact with the fuze pot all the while the projectile was in the hoist. In the case of the 5"/54, however, fuzes are not set until after the projectile has been removed from the hoist by the cradle and placed in the transfer tray. As soon as the transfer tray positions the projectile in direct alignment behind the fuze setter, the fuze pot mechanism of the fuze setter is brought into contact with the projectile fuze and the fuze is set. This function of extending (and retracting) the fuze pot is performed by the fuze pot extending and retracting mechanism. Figure 10-13 shows the fuze pot extending and retracting mechanism for the right fuze setting assembly.

The left and right fuze pot extending and retracting mechanisms are solenoid-operated hydraulic devices that extend and retract the fuze pots of the left and right fuze setters. They are identical in design and function, but are assembled as opposite hand arrangements. Each mechanism is an operational unit of the gun loading system and is accordingly assigned a control component designation letter. In the right unit, the electrical and hydraulic components are identified by the letter L, in the left unit by the letter M.

Each unit consists of a solenoid assembly and a valve block assembly. A fuze pot operating piston in the valve block is connected by a link to the fuze pot assembly of the fuze setter to the rear of the valve block. A rearward stroke of the piston extends the fuze pot, a forward stroke retracts it. The direction in which the piston moves is determined by a directional selector valve whose position is controlled by the solenoid assembly.

Solenoid Assembly

The solenoid assembly is installed in a housing secured to the top of the valve block. It consists of two push-type solenoids, two electrical interlock switch assemblies, a switch actuating mechanism, and a mechanism that transmits the motion of the solenoids to the selector valve in the valve block. The schematic view in figure 10-14 shows the arrangement of these components in the solenoid housing.



53.244
Figure 10-12.—Location of fuze setting equipment on slide.

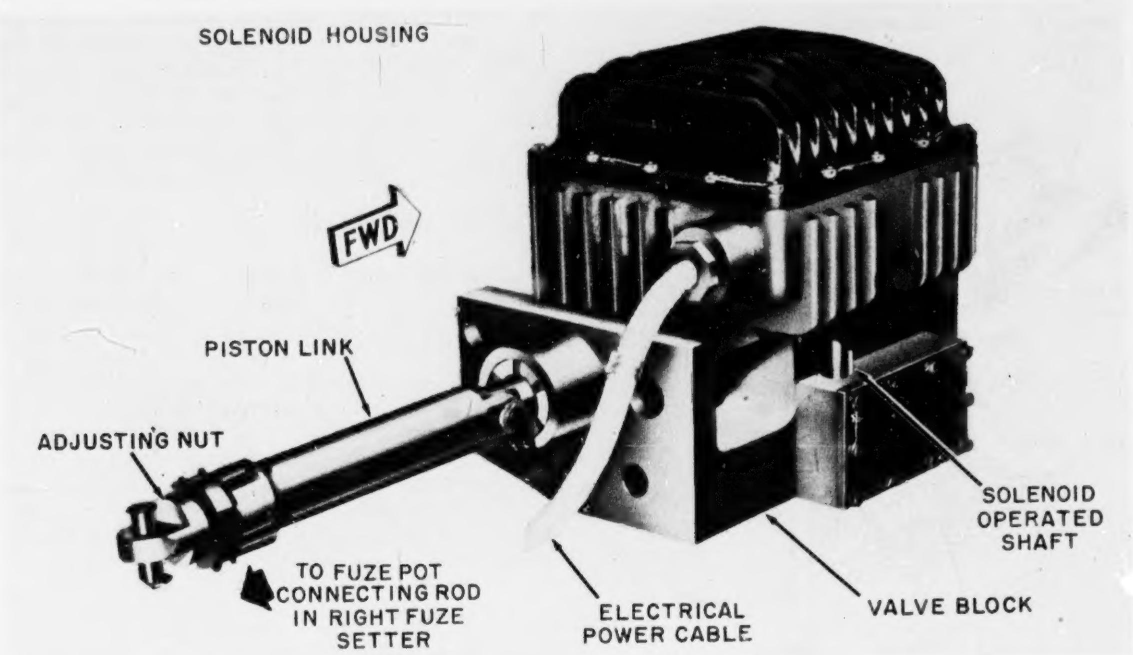
Solenoid SL1 controls the extend stroke of the right fuze pot operating piston; SL2 controls the retract stroke. (Solenoids SM1 and SM2 perform the same function for the left fuze pot operating piston.) The core rods of the solenoids are attached to the ends of a connecting arm. This arm is keyed at its midpoint to the upper end of a shaft that extends through the bottom of the solenoid housing and connects at its lower end to a valve operating lever. When either solenoid is energized the stroke of its core rod rotates the connecting arm about the vertical axis of the shaft, the rotation of the shaft turns the valve operating lever, and the lever positions the directional selector valve. The switch actuating mechanism rotates with the connecting arm and shaft, and closes switch IL101A when SL1 is energized, IL102A, B when SL2 is energized. On completion of each solenoid energization stroke, the movable elements of the solenoid assembly are held in position by a spring-loaded detent plunger that engages a locating detent in one end of the core rod connecting arm.

Valve Block Assembly

The valve block of each fuze pot extending and retracting mechanism contains the following hydraulic control elements:

1. Fuze pot operating piston.
2. Directional selector valve.
3. Flow control valve.
4. Check valve.

Figure 10-15 shows the arrangement of these elements in the valve block.



53.245
Figure 10-13. — Right fuze pot extending and retracting mechanism.

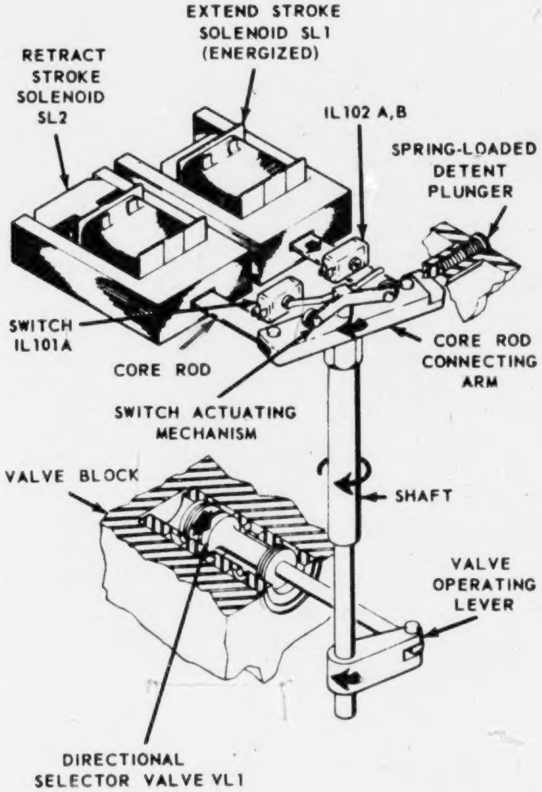
Two pipes supply the valve block with PA and PS fluid pressure from the main accumulator system; the PA fluid pressure is 1400-1500 psi, PS fluid pressure is 60-64 psi.

The fuze pot operating piston extends rearward out of the valve block and connects to a link that transmits the movement of the piston to the connecting rod of the fuze pot. PA and PS fluid pressures are applied to the ends of the piston via the directional selector valve. When PA pressure is applied to both ends of the piston, the greater working area on the forward end of the piston enables the pressure there to shift the piston rearward. This forces the piston link and fuze pot connecting rod rearward to extend the fuze pot.

When PA pressure is applied to the rod end of the piston and the head end is vented to the PS line, the piston moves into the forward end of its sleeve and retracts the fuze pot.

The flow control valve controls the terminal velocity of the piston stroke by metering the final flow of discharge fluid from the after end of the operating piston sleeve. During the last 5/8 inch of extend stroke travel, the action of the flow control valve limits the velocity of the piston, and hence that of the fuze pot, to 1 foot per second. This ensures that the fuze setting pawls will not be rammed over the projectile fuze and that the fuze pot gearing will not be damaged by a sudden stop. The piston is also buffed in both directions by deceleration grooves in the piston head which impart a dash-pot action as the head enters dead-end buffing chambers near the end of each stroke.

The check valve unseats and permits PA fluid to discharge from the after end of the operating piston sleeve during the extend stroke until the piston closes the check valve inlet port and forces the fluid to discharge via the flow control valve. The check valve then seats and prevents PA fluid from entering the space between the piston sleeve and the piston operating tube during the remainder of the extend stroke and throughout the subsequent retract stroke.



53.246

Figure 10-14.—Schematic view showing solenoid assembly of right fuze pot extending and retracting mechanism.

FUZE SETTER

In each mount installation, the left and right fuze setters are identical in design and function, and differ only in that one is a left-hand arrangement and the other is right-hand. The same fuze setter design is not used in all mounts, however. Some mounts are equipped with the Fuze Setter Mk 24 Mods 2 and 3, and others have the Mk 24 Mods 4 and 5. The Mods 2 and 3 and Mods 4 and 5 fuze setters differ primarily in that the former have mechanical backlash compensators while the latter have electrical backlash compensators. Unless otherwise noted, the text and illustrations that follow apply to all mods of the fuze setter.

Each fuze setter consists of a fuze pot mechanism and a receiver-regulator mounted in a single housing. The fuze pot mechanism is located in the bottom of the housing where it is mounted on a keyway so that it can slide rearward out of the housing to engage the fuze of the projectile in the transfer tray. The upper part of the housing contains the receiver-regulator, which applies the fuze setting orders to the fuze pot mechanism. Figure 10-16 shows the left fuze setter with covers removed.

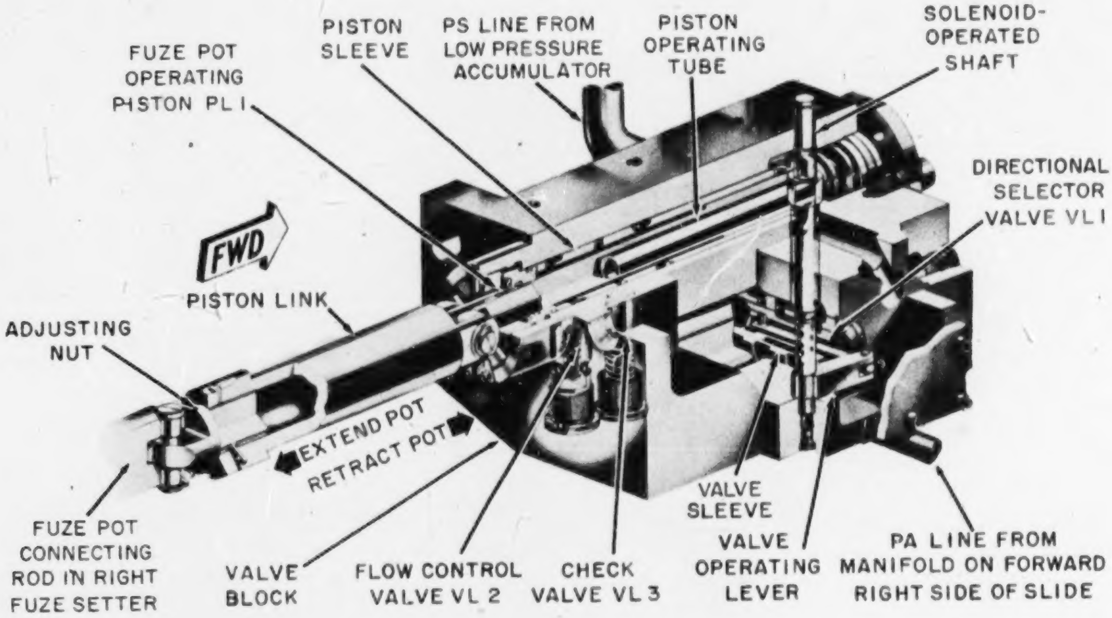
Fuze Pot Mechanism

The fuze pot mechanism is mounted on a guide key in the bottom of the fuze setter housing as shown in figure 10-17. Whenever a transfer tray holds a round of ammunition in readiness for automatic loading and the projectile of the round has a mechanical time fuze, the fuze pot mechanism extends from its housing, engages the fuze, and rotates the fuze timing elements in accordance with the drive applied to the mechanism by the receiver-regulator. Each fuze pot mechanism consists of the following subassemblies:

1. Fuze pot.
2. Gear box.
3. End bracket and connecting rod.

FUZE POT. Each fuze pot includes the following: a setting cup, ring, and pawl assembly; a holding cup, ring, and pawl assembly; a switch actuating mechanism; a fuze pot tube; and an end cover. The cup, ring, and pawl assemblies are driven by separate ring gears in the gear box, and rotate about a common axis. The fuze setting and holding pawls are mounted in the setting and holding rings (fig. 10-18), which are attached to the after ends of the setting and holding cups. The setting cup rotates on a ball bearing inside the holding cup, and the holding cup rotates on a ball bearing inside the fuze pot tube.

The cover plate at the bottom of the end cover (fig. 10-18) protects the actuating mechanism for switch SW-1. Switch SW-1 is mounted on the forward face of the end bracket (fig. 10-17). The actuating mechanism consists of a pivoted lever and a spring-loaded rod. The lever is pivoted near its upper end on pins anchored in retainer plates secured to the end cover. The top of the lever extends slightly above the lip of the fuze pot opening. The bottom is held against the face of the end cover by a small locking plate attached to the after end


FUZE POT OPERATING PISTON PL 1
PISTON SLEEVE
PS LINE FROM LOW PRESSURE ACCUMULATOR
PISTON OPERATING TUBE
SOLENOID-OPERATED SHAFT
DIRECTIONAL SELECTOR VALVE VL 1
FWD
PISTON LINK
ADJUSTING NUT
EXTEND POT
RETRACT POT
VALVE SLEEVE
FUZE POT CONNECTING ROD IN RIGHT FUZE SETTER
VALVE BLOCK
FLOW CONTROL VALVE VL 2
CHECK VALVE VL 3
VALVE OPERATING LEVER
PA LINE FROM MANIFOLD ON FORWARD RIGHT SIDE OF SLIDE

53.247

Figure 10-15.—Cutaway view of right fuze pot extending and retracting valve block.

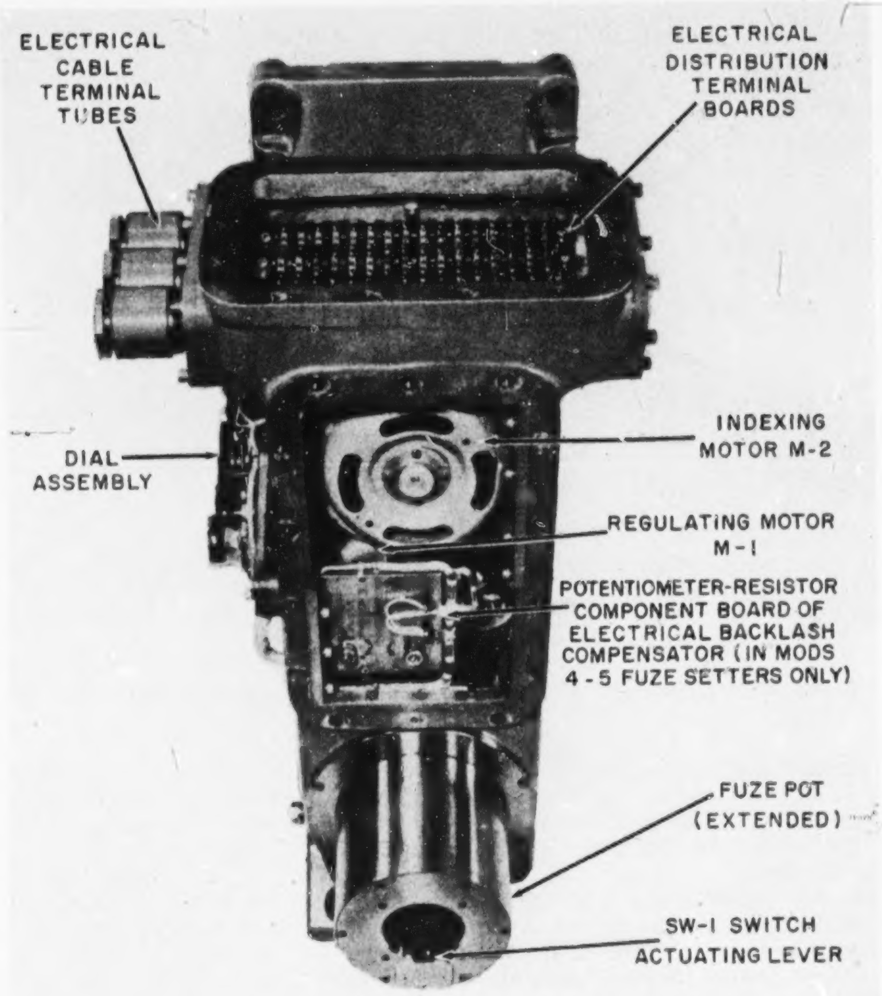
of the spring-loaded switch actuating rod. The rod extends through the bottom of the fuze pot tube and gear box as shown in figure 10-17, and transmits the motion of the lever to the actuating plunger of SW-1.

When the fuze pot extends over a projectile fuze, the base of the fuze contacts the top of the lever and pushes it against the face of the end cover. The lever then pivots, its lower end pulls the rod rearward against spring pressure, and the rod actuates SW-1. The closure of SW-1 actuates the indexing of the receiver-regulator.

The spring-loaded fuze setting pawl (figs. 10-17 and 10-18) is mounted in a ring attached to the after end of the setting cup. When the fuze pot is extended and the indexing drive rotates the setting cup, the setting pawl engages a slot in the upper or forward cap of the projectile fuze. The pawl is pivoted on a pin and extends into the fuze pot through a machined opening in the ring. A coil spring extends the pawl into the pot and permits it to retract into the ring when the pot is over a fuze but the pawl is not yet in alignment with the setting slot of the fuze.

The conical setting cup is actually the after end of a shaft whose forward end is supported by a ball bearing in the gear box. Two ring gears are mounted on a set of splines on the forward end of the shaft. The forward gear meshes with the rotor pinion of synchro control transformer SCT-2H (synchro differential generator SDG-2 in Mods 4 and 5 fuze setters). The after gear meshes with an end gear of differential D-2, and applies rotational drive to the setting cup, ring, and pawl assembly. (See figure 10-19).

The spring-loaded fuze holding pawl is mounted in a ring attached to the after end of the holding cup (figs. 10-17 and 10-18). When the fuze pot is extended and the indexing drive rotates the holding cup, the holding pawl engages a slot in the cap at the base of the projectile fuze. The conical holding cup forms the after end of a hollow shaft whose forward end is secured to a gear sleeve that rides on a ball bearing on the shaft of the setting cup. The gear on the forward end of the holding cup gear sleeve meshes with the rotor pinion of synchro differential generator SDG-1. The after gear meshes

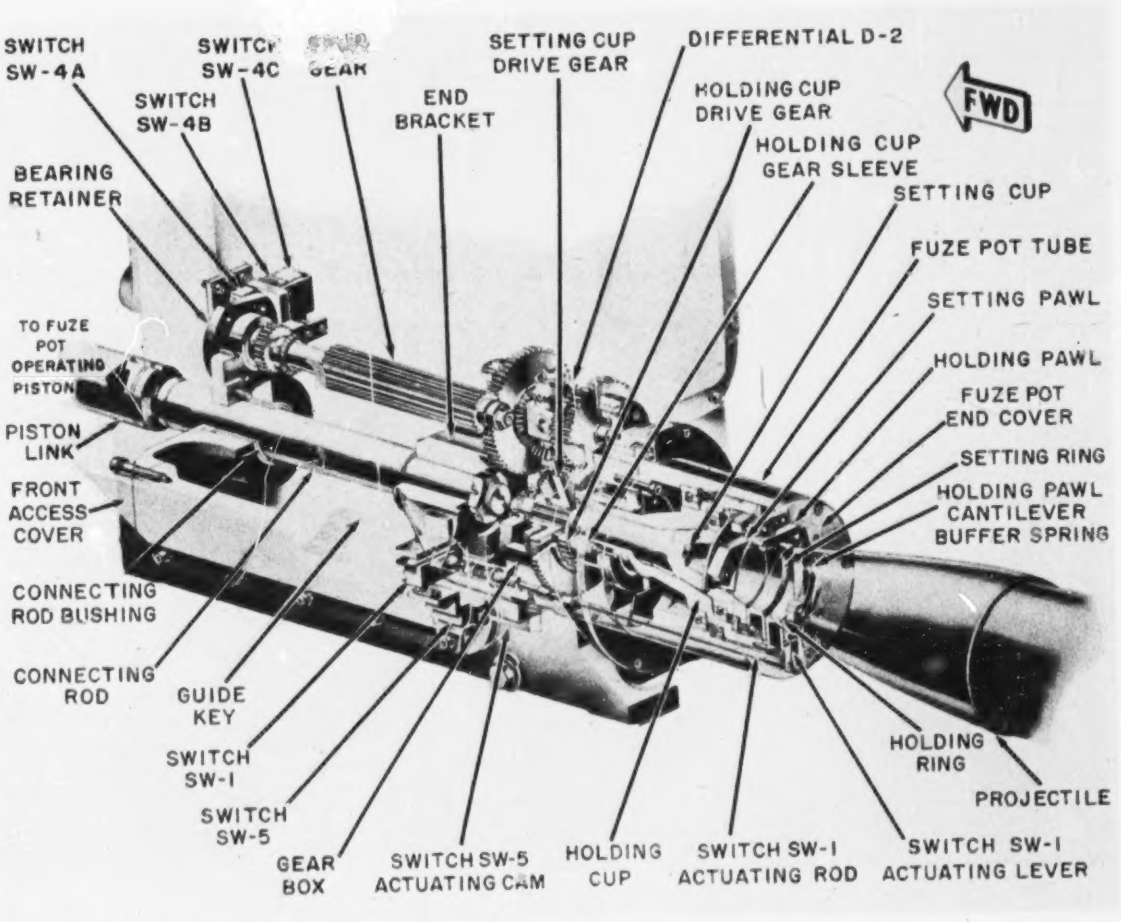

ELECTRICAL CABLE TERMINAL TUBES
ELECTRICAL DISTRIBUTION TERMINAL BOARDS
INDEXING MOTOR M-2
DIAL ASSEMBLY
REGULATING MOTOR M-1
POTENTIOMETER-RESISTOR COMPONENT BOARD OF ELECTRICAL BACKLASH COMPENSATOR (IN MODS 4-5 FUZE SETTERS ONLY)
FUZE POT (EXTENDED)
SW-1 SWITCH ACTUATING LEVER

53.248
Figure 10-16.—Left fuze setter.

with a gear driven by differential D-2, and drives the holding cup assembly around the outside of the setting cup. (See figure 10-19.)

GEAR BOX. The gear box (fig. 10-17) is a nearly cylindrical frame that supports the entire fuze pot mechanism in the fuze setter housing. It houses the fuze pot drive gears, differential D-2, synchro differential generator SDG-1, and synchro control transformer SCT-2H (synchro differential generator SDG-2 in Mods 4 and 5 fuze setters). A cam plate attached to the underside of the gear box actuates switch SW-5, which is mounted in the bottom of the fuze setter housing. (See figure 10-19.)

END BRACKET and CONNECTING ROD. The end bracket and connecting rod (fig. 10-17) connect the fuze pot mechanism to the fuze pot operating piston in the fuze pot extending and retracting mechanism valve block (fig. 10-15).

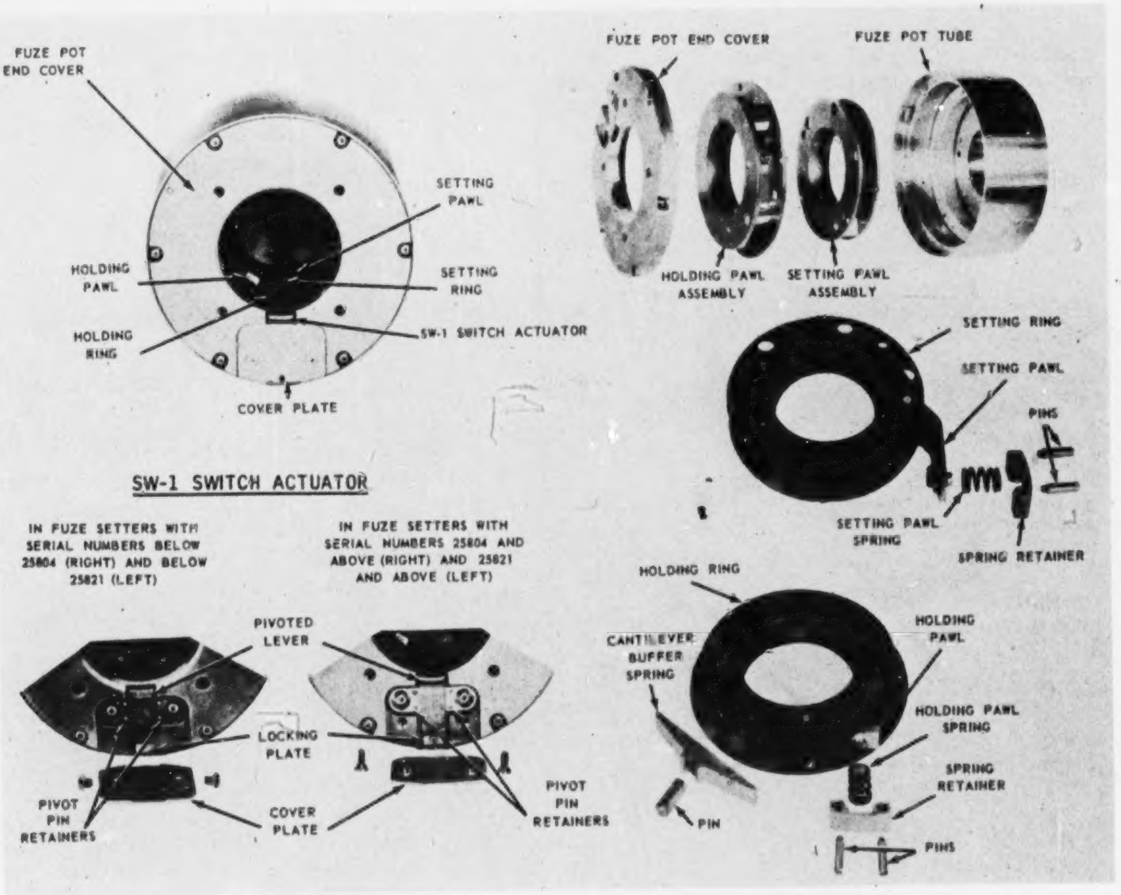

SWITCH SW-4A
SWITCH SW-4C
SPUR GEAR
SETTING CUP DRIVE GEAR
DIFFERENTIAL D-2
SWITCH SW-4B
END BRACKET
HOLDING CUP DRIVE GEAR
FWD
HOLDING CUP GEAR SLEEVE
BEARING RETAINER
SETTING CUP
FUZE POT TUBE
SETTING PAWL
TO FUZE POT OPERATING PISTON
HOLDING PAWL
FUZE POT END COVER
PISTON LINK
SETTING RING
FRONT ACCESS COVER
HOLDING PAWL CANTILEVER BUFFER SPRING
CONNECTING ROD BUSHING
CONNECTING ROD
GUIDE KEY
HOLDING RING
SWITCH SW-1
PROJECTILE
SWITCH SW-5
GEAR BOX
SWITCH SW-5 ACTUATING CAM
HOLDING CUP
SWITCH SW-1 ACTUATING ROD
SWITCH SW-1 ACTUATING LEVER

53.249
Figure 10-17.—Cutaway view of fuze pot mechanism.

Receiver-Regulator

The receiver-regulator receives fuze order signals from a remote computer, compares them with the positions of the fuze pot pawls, and generates error signals that indicate the measure by which the pawls are out of correspondence with the order signals. It then sends these error signals to the fuze setter amplifier where their voltages are amplified and sent back to a regulating motor in the receiver-regulator. This motor runs all the time and holds the fuze pot pawls constantly in synchronism with the fuze setting orders.

When the fuze pot is extended over a projectile fuze, an indexing motor in the regulator drives the pawls through an integral number of dead turns of relative rotation. This ensures positive engagement of the pawls with the fuze slots, and synchronizes the timing elements of the fuze with the coarse one-speed fuze setting order. (When the pot is extended and the indexing motor is rotating, the fine five-speed fuze setting order is not applied to the fuze-setting pawls.) When the indexing motor stops, the regulating motor again applies both the coarse and fine fuze setting orders to the pawls; and the fuze is held in exact synchronism with the orders.


FUZE POT END COVER
SETTING PAWL
HOLDING PAWL
SETTING RING
HOLDING RING
SW-1 SWITCH ACTUATOR
COVER PLATE
FUZE POT END COVER
FUZE POT TUBE
HOLDING PAWL ASSEMBLY
SETTING PAWL ASSEMBLY
SETTING RING
SETTING PAWL
PINS
SETTING PAWL SPRING
SPRING RETAINER
SW-1 SWITCH ACTUATOR
IN FUZE SETTERS WITH SERIAL NUMBERS BELOW 25804 (RIGHT) AND BELOW 25821 (LEFT)
IN FUZE SETTERS WITH SERIAL NUMBERS 25804 AND ABOVE (RIGHT) AND 25821 AND ABOVE (LEFT)
PIVOTED LEVER
LOCKING PLATE
PIVOT PIN RETAINERS
COVER PLATE
PIVOT PIN RETAINERS
HOLDING RING
CANTILEVER BUFFER SPRING
HOLDING PAWL
HOLDING PAWL SPRING
SPRING RETAINER
PIN
PINS

53.250
Figure 10-18.—Fuze pot assembly.

During the time that the indexing motor is in operation, the rotational outputs of the indexing and regulating drives are combined by a bevel gear differential (D-1) and then applied as a single rotational input to the fuze pot mechanism, the indicating dial assembly, and the one-speed fuze order synchro control transformer SCT-2L.

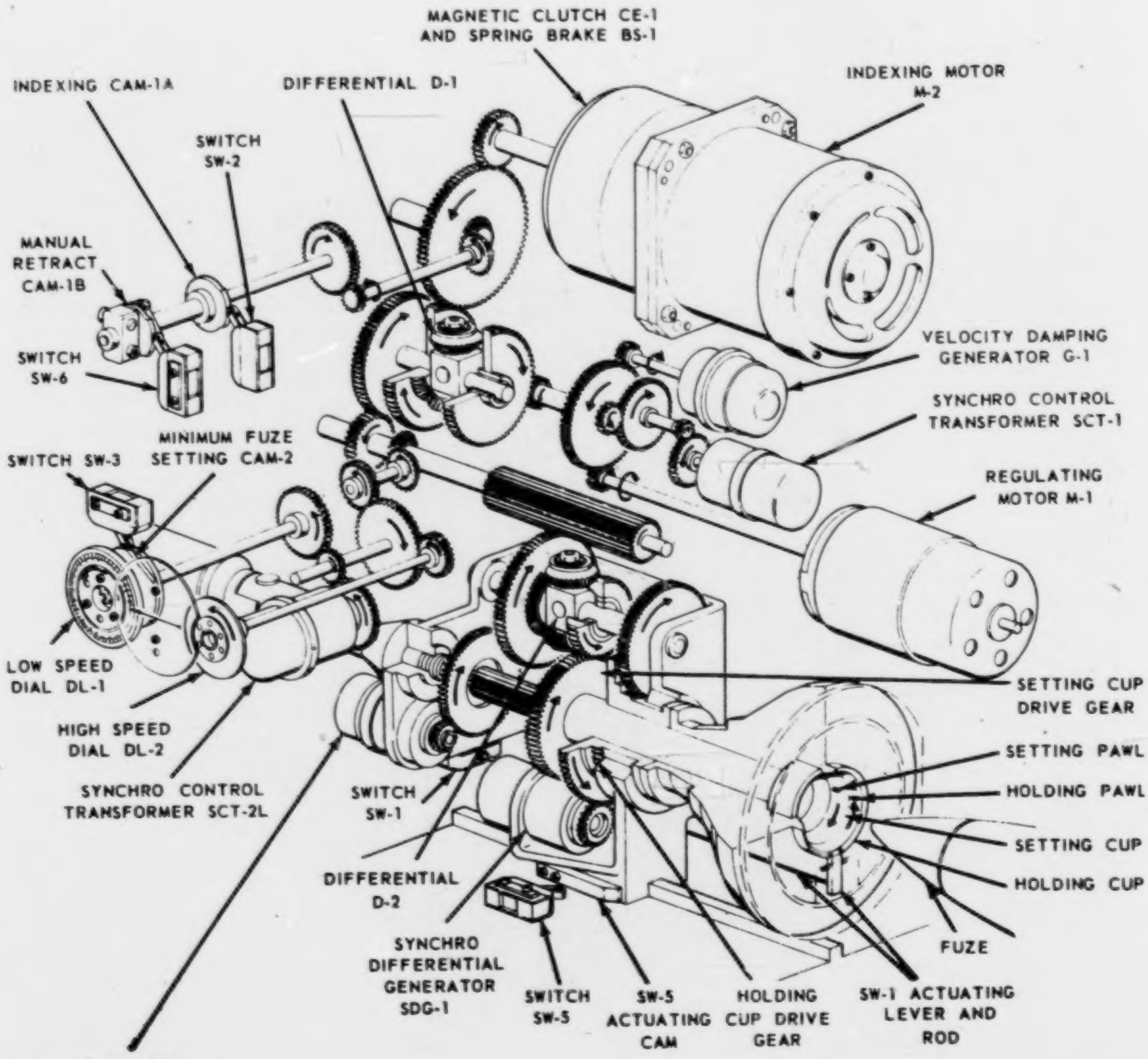
Each receiver-regulator is thus an assembly of the following:

1. Regulating drive.
2. Indexing drive.
3. Differential D-1.

REGULATING DRIVE. The regulating drive (figs. 10-19 and 10-20) is a servomechanism that consists of the following control elements:

- Regulating motor M-1.
- Synchro control transformers:
    - Mods 2-3 fuze setters -
        - SCT-1
        - SCT-2H
        - SCT-2L
    - Mods 4-5 fuze setters -
        - SCT-1
        - SCT-2L
- Synchro differential generators:
    - Mods 2-3 fuze setters -
        - SDG-1

ONE REVOLUTION OF FUZE = 360/7 SECONDS OF FUZE TIME


MAGNETIC CLUTCH CE-1
AND SPRING BRAKE BS-1
INDEXING CAM-1A
DIFFERENTIAL D-1
INDEXING MOTOR M-2
SWITCH SW-2
MANUAL RETRACT CAM-1B
SWITCH SW-6
VELOCITY DAMPING GENERATOR G-1
SYNCHRO CONTROL TRANSFORMER SCT-1
MINIMUM FUZE SETTING CAM-2
SWITCH SW-3
REGULATING MOTOR M-1
LOW SPEED DIAL DL-1
SETTING CUP DRIVE GEAR
HIGH SPEED DIAL DL-2
SETTING PAWL
SYNCHRO CONTROL TRANSFORMER SCT-2L
SWITCH SW-1
HOLDING PAWL
SETTING CUP
DIFFERENTIAL D-2
HOLDING CUP
FUZE
SYNCHRO DIFFERENTIAL GENERATOR SDG-1
SWITCH SW-5
SW-5 ACTUATING CAM
HOLDING CUP DRIVE GEAR
SW-1 ACTUATING LEVER AND ROD

SYNCHRO CONTROL
TRANSFORMER SCT-2H:
MOD 2 - UP TO AND INCLUDING SERIAL NO. 25601
MOD 3 - UP TO AND INCLUDING SERIAL NO. 25606

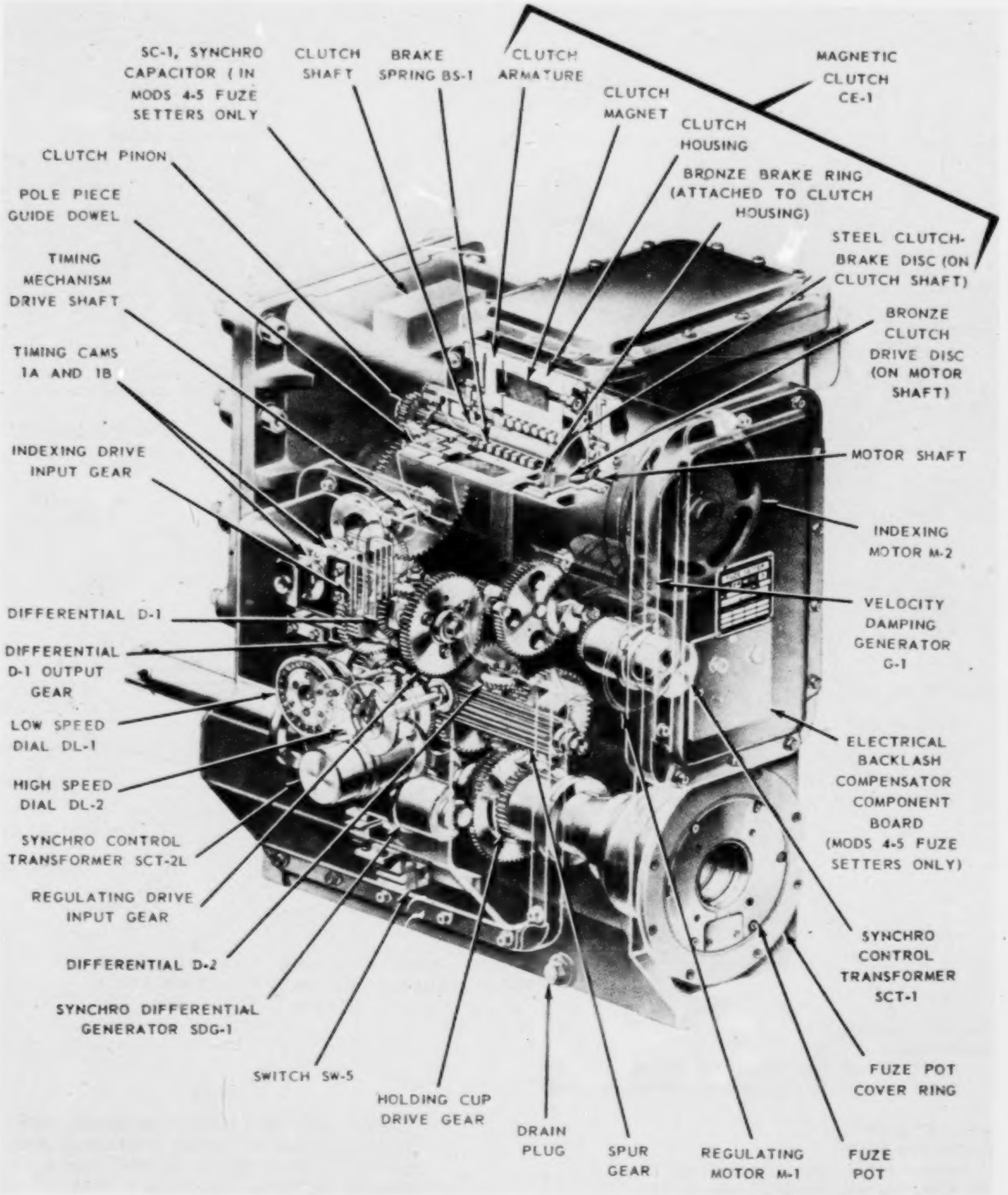
SYNCHRO DIFFERENTIAL
GENERATOR SDG-2:
MOD 4 - SERIAL NO. 25714 AND ABOVE
MOD 5 - SERIAL NO. 25730 AND ABOVE

NOTE

ARROWS SHOW ROTATION OF ELEMENTS WHEN FUZE SETTING IS BEING DECREASED AND INDEXING MOTOR M-2 IS DRIVING PAWLS TO ENGAGE SLOTS IN PROJECTILE FUZE.

53.251

Figure 10-19. — Mechanical schematic of left fuze setter.


SC-1, SYNCHRO CAPACITOR (IN MODS 4-5 FUZE SETTERS ONLY
CLUTCH SHAFT
BRAKE SPRING BS-1
CLUTCH ARMATURE
MAGNETIC CLUTCH CE-1
CLUTCH MAGNET
CLUTCH HOUSING
CLUTCH PINON
BRONZE BRAKE RING (ATTACHED TO CLUTCH HOUSING)
POLE PIECE GUIDE DOWEL
STEEL CLUTCH-BRAKE DISC (ON CLUTCH SHAFT)
TIMING MECHANISM DRIVE SHAFT
BRONZE CLUTCH DRIVE DISC (ON MOTOR SHAFT)
TIMING CAMS 1A AND 1B
INDEXING DRIVE INPUT GEAR
MOTOR SHAFT
INDEXING MOTOR M-2
VELOCITY DAMPING GENERATOR G-1
DIFFERENTIAL D-1
DIFFERENTIAL D-1 OUTPUT GEAR
LOW SPEED DIAL DL-1
ELECTRICAL BACKLASH COMPENSATOR COMPONENT BOARD (MODS 4-5 FUZE SETTERS ONLY)
HIGH SPEED DIAL DL-2
SYNCHRO CONTROL TRANSFORMER SCT-2L
REGULATING DRIVE INPUT GEAR
SYNCHRO CONTROL TRANSFORMER SCT-1
DIFFERENTIAL D-2
SYNCHRO DIFFERENTIAL GENERATOR SDG-1
SWITCH SW-5
FUZE POT COVER RING
HOLDING CUP DRIVE GEAR
DRAIN PLUG
SPUR GEAR
REGULATING MOTOR M-1
FUZE POT

53.252
Figure 10-20.—(Left) Fuze setter Mk 24 Mod 3.

- Mods 4-5 fuze setters-
  - SDG-1
  - SDG-2
- Differential D-1
- Indicating dials DD-1 and DL-2
- Minimum fuze setting mechanism:
  - Cam-2
  - Switch SW-3
- Velocity damping generator G-1
- Backlash compensator:
  - Mods 2-3 fuze setters-
    - Mechanical, installed on synchro control transformer SCT-2H
  - Mods 4-5 fuze setters-
    - Electrical, installed in the fuze setter housing (fig. 10-16) on studs extending rearward from the regulating motor mounting (plus components in the P2 amplifier panel).

Fuze setting orders are transmitted to the regulator as 1X and 5X synchro signals from a remote computer. The 1X, or one-speed, signals are coarse fuze setting orders that set fuze time down to 2.26 seconds. They are applied to the stators of synchro control transformers SCT-1 and SCT-2L. The 5X, or five-speed, signals are fine fuze setting orders that set fuze time within 0.15 of a second. They are applied on the stator of synchro control transformer SCT-2H (synchro differential generator SDG-2 in Mods 4 and 5 fuze setters) after being transmitted through synchro differential generator SDG-1.

If the fuze pot pawls are far from synchronism with the fuze setting orders, or during the time that indexing motor M-2 is applying the 2-1/4 turns of relative rotation to the fuze pot pawls, coarse 1X signals are selected to be applied to the amplifier. If the pawls are less than 15.8 degrees (2.26 seconds of fuze time) from synchronism with the orders, the fine 5X signals are selected.

Before being applied to the amplifier, the error signal is modified by a damping voltage generated by velocity damping generator G-1, which is driven by regulating motor M-1. The purpose of the damping voltage is to eliminate overshooting and minimize oscillation in the amplifier servosystem.

In the four-stage, high-gain power amplifier, the damped error voltage is amplified to a level capable of operating regulating motor M-1. The rotational output of regulating motor is applied directly to velocity damping generator G-1 and the rotor of SCT-1, and through bevel gear differential D-1 to the following components:

1. Indicating dials DL-1 and DL-2.
2. Minimum fuze setting cam-2.
3. The rotor of SCT-2L.
4. Fuze pot bevel gear differential D-2.

From differential D-2, the regulating drive is transmitted to:

1. The rotor of SDG-1.
2. The rotor of SCT-2H (SDG-2).
3. The getting and holding pawls of the fuze pot.

The purpose of the backlash compensator (both the mechanical and the electrical) is to eliminate the fuze setting error caused by deflection and backlash in the fuze pot gearing. Since there is more play in the gear train between differential D-2 and the fuze pot pawls than there is in the train between D-2 and SCT-2H (SDG-2 in Mods 4 and 5 fuze setters with electrical backlash compensators), the setting of the pawls tends to lag slightly behind the fuze order.

The mechanical backlash compensator corrects this error by introducing play into the gear train between differential D-2 and SCT-2H so that the play in this transmission is equal to that between D-2 and the fuze pot pawls. The electrical backlash compensator corrects this error by modifying the 5X error signal from SDG-2.

INDEXING DRIVE. The indexing drive is an intermittently operated drive mechanism that introduces a 3/4-turn of relative rotation to the fuze pot pawls during each pot retract stroke, and 2-1/4 turns whenever the pot is extended over a projectile fuze. The following components (See figures 10-19 and 10-20) are involved in the operation of the indexing drive:

- Indexing motor M-2
- Magnetic clutch CE-1
- Spring brake BS-1
- Timing mechanism:
  - Cam-1A
  - Cam-1B
  - Switch SW-2
  - Switch SW-6

The indexing motor is a constant-speed, nonreversible induction motor that drives the fuze pot pawls through three dead turns of relative rotation during each fuze setting operation. This action ensures positive engagement of the pawls in the fuze slots, and leaves the pawls in positions corresponding to the coarse one-speed fuze setting order. The indexing motor runs continuously, but its rotation is applied to the fuze pot pawls only when magnetic clutch CE-1 is energized. When the clutch is deenergized, the rotation of the motor cannot be transmitted to the indexing drive, and a spring brake BS-1 holds the drive stationary.

If the gun loading system is in auto power operation and the transfer tray opposite the fuze setter is loaded with a round with an MT fuze, the fuze pot extending and retracting mechanism will automatically extend the fuze pot rearward from the fuze setter and place the spring-loaded setting and holding pawls of the pot in contact with the projectile fuze. When the fuze pot reaches its fully extended position, a cam action opens switch SW-5, and the projectile fuze contacts the actuating mechanism closes switch SW-1.

The closure of SW-1 actuates the indexing drive of the receiver-regulator. A circuit through SW-2 and SW-1 then energizes magnetic clutch CE-1. The clutch then compresses brake spring BS-1 and transmits the rotation of indexing M-2 to all of the components that are already being driven by regulating motor M-1 through differential D-1.

The indexing motor drives the setting and holding pawls of the extended fuze pot through 2-1/4 turns of relative rotation. Cam-1A then opens switch SW-2 (fig. 10-19), clutch CE-1 deenergizes and disengages the indexing motor from its output shaft, and spring brake BS-1 extends and stops the rotation of the indexing drive. Simultaneously, cam-1B closes switch SW-6A (fig. 10-19) in control circuit of the fuze pot retract stroke solenoid to indicate that the 2-1/4 turns of indexing rotation have been applied to the fuze pot pawls.

At the time the 2-1/4 turns are being applied to the pawls, they have already been rotated through a 3/4 turn with respect to one another by the action of the indexing drive during the preceding fuze pot retract stroke. Consequently, when the indexing drive completes its 2-1/4 turn cycle, a total of three dead turns have actually been applied to the pawls by indexing motor M-2.

The exact number of indexing turns required is determined as follows:

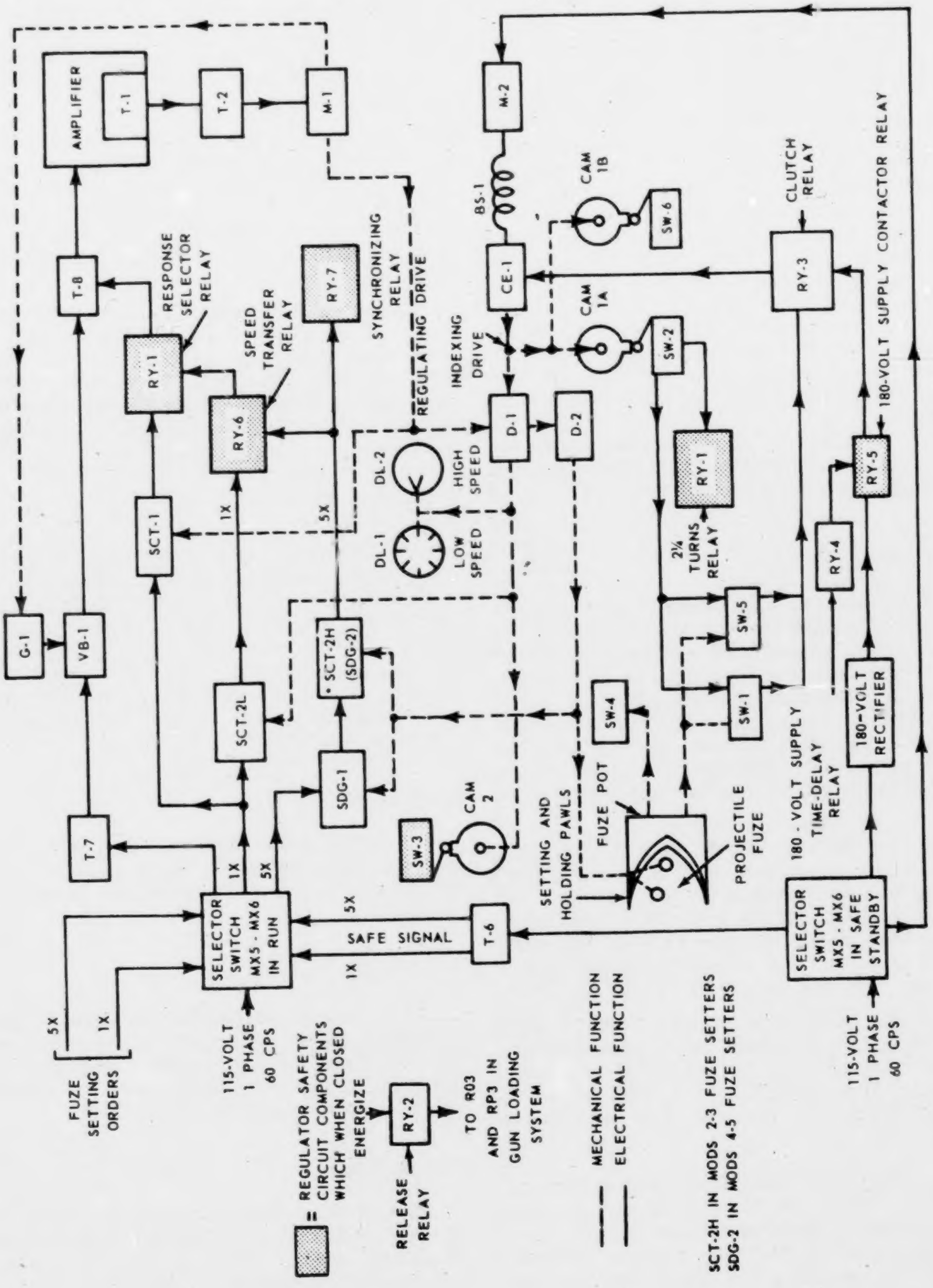
When a maximum condition of pawl and slot misalignment exists, the pawls must be driven through two full turns of relative rotation to engage the slots of the projectile fuze. To these two turns, a 1/4 turn is added to compensate for a 1/4 turn that the regulating motor may be subtracting from the pawls while they are being driven by the indexing motor.

That makes 2-1/4 turns. An additional 3/4 turn is added to keep the rotors of the synchro control transformers and differential generators in synchronism with the incoming fuze order signals, making an integral number of three dead turns.

The indexing cycle is comparable to that part of the rotation of the inner socket of the 5''/38 projectile flight which is imparted during hoisting by the sprocket walking up the fuze chain. Each operation serves a like purpose, that of ensuring positive engagement with the pawls and rotating the fuze time ring in accordance with the position of the setting pawls (during cycling or hoisting). Further settings can be made in both systems by the regulating drive but only, of course, while the fuze and fuze pot remain in engagement. It should be noted that, in the case of the 5''/38, less rotation is required to ensure positive engagement of the pawls because a fixed reference position is provided by the fixed lug of the fuze being held in the V-slot of the outer socket of the fuze pot.

While the indexing motor is applying the 2-1/4 turns, switch SW-2 keeps relay RY-1 energized, and the relay applies the coarse 1X error signals from SCT-1 to the amplifier (fig. 10-21). When SW-2 is opened by cam-1A at the end of the 2-1/4 turn cycle, RY-1 deenergizes along with clutch relay RY-3. RY-1 then cuts off the 1X error signal from SCT-1 and selects the output of relay RY-6 for transmission to the amplifier. If the pawls are far from synchronism, RY-6 transmits the 1X signals from SCT-2L. If the pawls are close to synchronism, RY-6 transmits the 5X signals from SCT-2H (SDG-2).

Regulator Safety Circuit. Before the fuze pot can be retracted from the projectile fuze, release relay RY-2 must be energized by the regulator safety circuit. This circuit consists of switch SW-3 and relays RY-1, RY-5, RY-6 and RY-7 (see figure 10-21). Switch SW-3 is actuated by cam-2, which can be adjusted to set minimum allowable fuze settings between the


FUZE SETTING ORDERS
5X
1X
115-VOLT 1 PHASE 60 CPS
SELECTOR SWITCH MX5 - MX6 IN RUN
SAFE SIGNAL
T-6
T-7
G-1
VB-1
T-8
AMPLIFIER
T-1
T-2
M-1
SCT-1
SCT-2L
SCT-2H (SDG-2)
SDG-1
RY-1
RESPONSE SELECTOR RELAY
RY-6
SPEED TRANSFER RELAY
RY-7
SYNCHRONIZING RELAY
REGULATING DRIVE
DL-1
LOW SPEED
DL-2
HIGH SPEED
INDEXING DRIVE
D-1
D-2
CE-1
BS-1
M-2
CAM 1A
CAM 1B
SW-6
SW-2
RY-1
2¼ TURNS RELAY
SW-5
SW-1
SW-4
CAM 2
SW-3
SETTING AND HOLDING PAWLS
FUZE POT
PROJECTILE FUZE
180 - VOLT SUPPLY TIME-DELAY RELAY
180-VOLT RECTIFIER
RY-4
RY-5
180-VOLT SUPPLY CONTACTOR RELAY
RY-3
CLUTCH RELAY
SELECTOR SWITCH MX5 - MX6 IN SAFE STANDBY
115-VOLT 1 PHASE 60 CPS
= REGULATOR SAFETY CIRCUIT COMPONENTS WHICH WHEN CLOSED ENERGIZE
RY-2
RELEASE RELAY
TO R03 AND RP3 IN GUN LOADING SYSTEM
MECHANICAL FUNCTION
ELECTRICAL FUNCTION
SCT-2H IN MODS 2-3 FUZE SETTERS
SDG-2 IN MODS 4-5 FUZE SETTERS

53.253

Figure 10-21.—Functional diagram of fuze setter systems.

limits of zero and five seconds. If the setting is less than the minimum allowable value, cam-2 opens SW-3 and prevents retraction of the fuze pot until the fuze order increases to an above minimum value or a "safe" setting is applied to the fuze (MX5 or MX6 at SAFE-STANDBY).

Relay RY-1 closes in the regulator safety circuit only when the 2-1/4 turn indexing cycle has been completed. The closure of relay RY-5 in the safety circuit indicates that the magnetic clutch CE-1 has been properly energized during the indexing cycle. When relay RY-6 closes in the safety circuit, it indicates that the fine 5X error signal from SCT-2H (SDG-2) is being applied to the amplifier. Relay RY-7 closes in the safety circuit when the fuze pot pawls are in exact synchronism with the fine 5X fuze setting order (the error does not exceed 0.15 seconds).

When the above listed components are closed in the safety circuit, release relay RY-2 energizes and permits the fuze pot to retract.

Safe Fuze Setting Circuit

If a projectile fuze is being set and the order is given to secure the gun loading system, or if for any other reason it is necessary to remove from a transfer tray a projectile whose fuze is being set, the fuze selector switch is turned to the SAFE-STANDBY position. The fuze selector switches are located on the gun captain's P4 control panel. The switches are identified as MX5 for the right fuze setter and MX6 for the left.

With the switch at SAFE-STANDBY, safe signal transformer T-6 applies several fixed voltages to the stators of SCT-1, SCT-2L, and SDG-1 (fig. 10-21). These voltages are equivalent to a synchro signal of approximately 100 volts maximum, and cause regulating motor M-1 to drive the fuze pot pawls to "safe" positions.

When the pawls have placed a "safe" setting on the fuze, the regulator safety circuit closes, and the fuze pot can be retracted in manual operation. The projectile can then be safely unloaded from the transfer tray and stowed below.

DIFFERENTIAL D-1. Bevel gear differential D-1 (figs. 10-19, 10-20, and 10-21) combines the rotational outputs of regulating motor M-1 and indexing motor M-2 into a single rotational input to the indicating dial assembly, the rotor of SCT-2L, the minimum fuze setting cam-2, and the fuze pot differential D-2. When the indexing drive is stopped by brake BS-1, differential D-1 transmits only the output of motor M-1 to the above elements.

The forward gear of the differential is driven by the indexing drive, the opposite end gear by the regulating drive. A shaft on the forward side of the spider extends through a bearing in the forward differential gear and transmits the rotation of the spider to the differential output gear.

The rotational output of differential D-1 is transmitted to fuze pot differential D-2 by a long spur gear that meshes with the forward gear of D-2. This spur gear is 6-3/4 inches long and allows the fuze pot mechanism a maximum stroke of 6-1/8 inches without becoming unmeshed.

AMPLIFIER

The regulator amplifier is a four-stage, high-gain power amplifier with a maximum power output of 75 watts at 90 volts. It amplifies the error voltages produced by the receiver-regulator and applies its power output to the control field of regulating motor M-1. The amplifier is located in the P2 amplifier panel (fig. 10-22) and consists of four amplifying stages and a phase shifter network.

First Stage

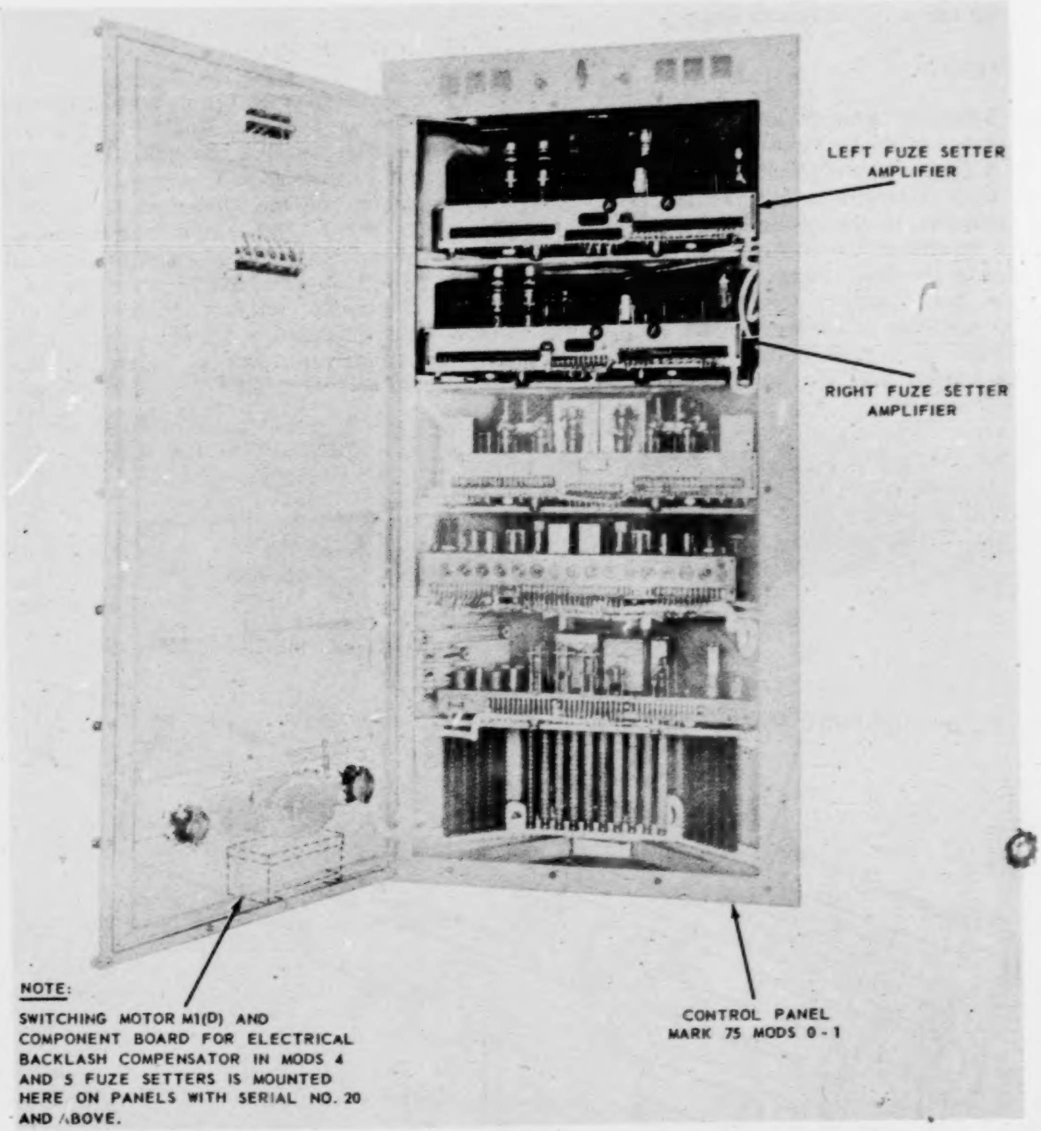
The first stage consists of a 6SJ7 pentode vacuum tube operating as a class A voltage amplifier. Its output is applied to a phase shifter network.

Phase Shifter Network

This resistor-capacitor network is placed between the first and second stages of the amplifier to compensate for the phase shift that occurs between the synchro stators and the secondary of amplifier output transformer T-2.

Second Stage

The second stage consists of a twin triode 6SL7GT tube that operates as a Class A voltage amplifier and a phase inverter to drive the push-pull third stage of the amplifier.


LEFT FUZE SETTER AMPLIFIER
RIGHT FUZE SETTER AMPLIFIER
NOTE:
SWITCHING MOTOR M1(D) AND COMPONENT BOARD FOR ELECTRICAL BACKLASH COMPENSATOR IN MODS 4 AND 5 FUZE SETTERS IS MOUNTED HERE ON PANELS WITH SERIAL NO. 20 AND ABOVE.
CONTROL PANEL MARK 75 MODS 0 - 1

53.254

Figure 10-22.—Location of fuze setter amplifier in P2 amplifier panel.

Third Stage

The third stage consists of two 6V6 beam-power tubes which operate as a Class AB1 push-pull amplifier in conjunction with a coupling transformer. The voltages induced in the secondary of the transformer are applied to the grids of the tubes in the fourth stage.

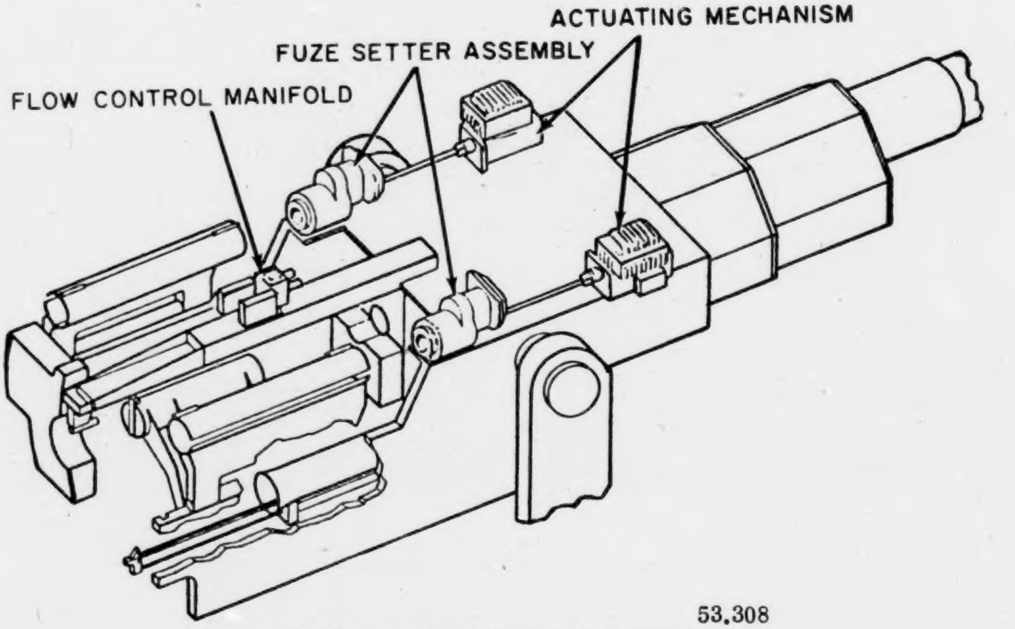
Fourth Stage

The fourth or power output stage contains two 811 power tubes that operate at a high power level as a Class B push-pull amplifier in conjunction with a power output transformer. The voltage induced in the secondary of the transformer is applied to the control field of regulating motor M-1 in the fuze setter.

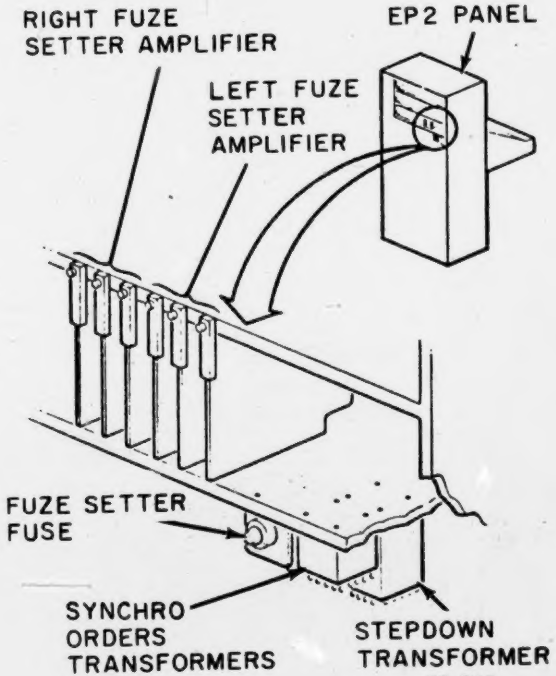
A new fuze setter, the Mk 27, has been developed for use with the 5''/54 Mod 9 gun mount. This new fuze setter is substantially lighter in weight than the Mk 24 presently used in the Mod's 1-8 mounts. It also has fewer moving parts, employs solid state amplifiers (electronic servo control units) and is more accurate than the Mk 24 fuze setters. A fuze setter similar to the Mk 27 will be employed in the new 5''/54 Mk 45 light weight gun mounts and the Mk 42 Mod 10.

FUZE SETTER MK 27

The Mk 27 fuze setter is a redesigned version of the one used on the Mod 1 thru 8 gun mounts. With the exception of the actuating mechanisms (fuze pot extending and retracting mechanism), the redesign of the fuze setter is almost 100 percent. The Mk 27 fuze setter is hydraulically operated and electromechanically controlled. The fuze setter (figure 10-23) consists of a fuze setter assembly, an actuating mechanism, and a flow control valve manifold. Each fuze setter has an amplifier which is located in the mount captain's control panel (EP-2 panel), figure 10-24.



53.308
Figure 10-23.—Fuze setter general arrangement.


RIGHT FUZE SETTER AMPLIFIER
EP2 PANEL
LEFT FUZE SETTER AMPLIFIER
FUZE SETTER FUSE
SYNCHRO ORDERS TRANSFORMERS
STEPDOWN TRANSFORMER

53.309
Figure 10-24.—Fuze setter amplifier.

FUZE SETTER ASSEMBLY

The fuze setter assembly consists of a housing, a fuze pot, a hydraulic motor (B-end), a servo valve, a tachometer, synchros, and the gearing required to index and set the projectile's fuze. This assembly is not only smaller in size, lighter in weight, and less complicated than the one used with the Mod 1 thru 8 mounts, but it is mounted to the gun housing in such a manner that it can be moved fore and aft. This movement is necessary in the fuze setter assembly because the fuze pot is not designed to be extended and retracted within the assembly as it is in the Mod 1 thru 8 mounts. Thus, the term extend and retract fuze setter is used in the writeup for the Mk 27 rather than the term extend and retract fuze pot.

HOUSING.—The housing (figure 10-25) encloses all of the fuze setter parts except the B-end and the servo valve.

FUZE POT.—The fuze pot (figure 10-25) is a round extension on the rear side of the fuze setter housing. It has a cone-shaped opening that fits onto the fuze on the nose of the projectile. Two spring loaded pawls, driven by a series of differential gears, rotate to set the fuze.

TACHOMETER.—The tachometer is mounted inside the fuze setter housing and is connected to the differential gearing. The tachometer turns as the pawls revolve. The tachometer shaft contains a dial which indicates fuze time settings through a small window in the front side of the fuze setter.

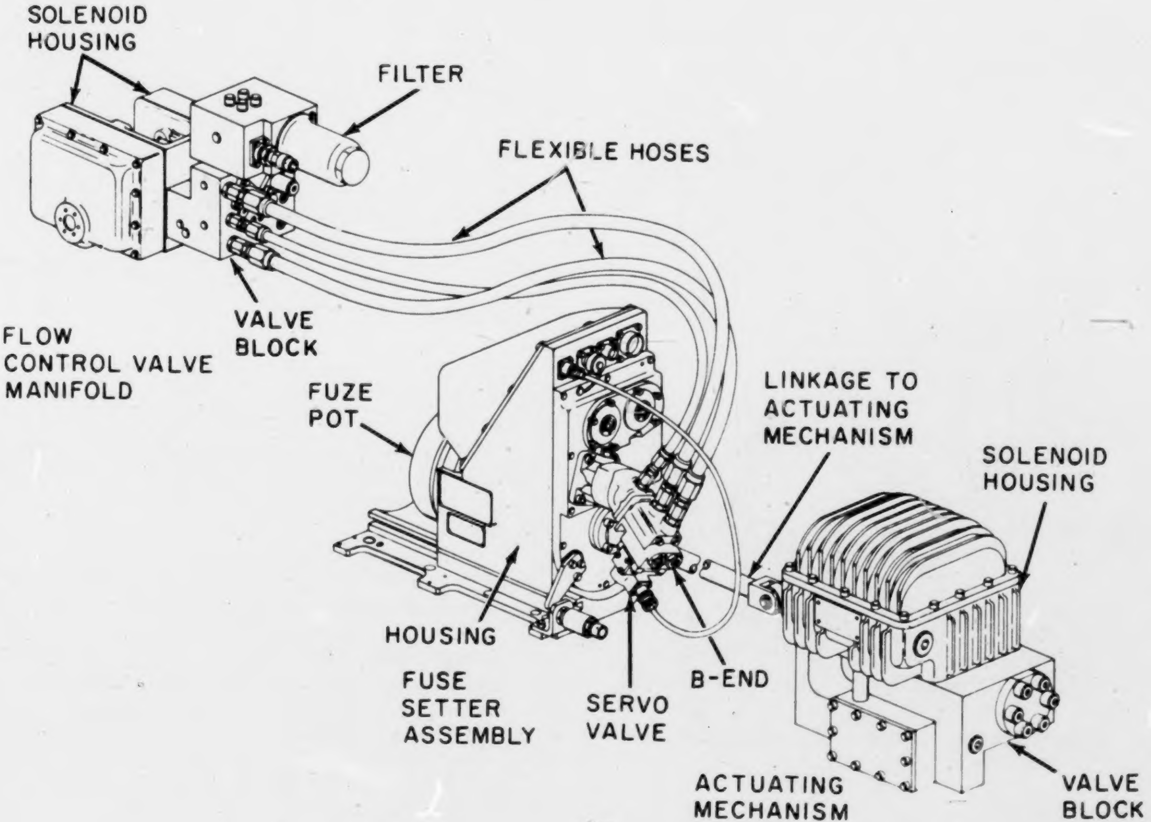
SYNCHROS.—Synchro control transformers, mounted inside the fuze setter housing, are connected to the differential gearing of each fuze setter. They turn at either the same speed as the pawls or five times as fast as the pawls to give coarse and fine indications of relative pawl positions.

B-END MOTOR.—A small B-end motor (figure 10-25) is mounted to the front surface of the fuze setter housing. The motor is smaller than other hydraulic motors used to power the gun mount. The B-end uses pressurized hydraulic fluid from the accumulator to turn the fuze setting pawls through gearing. The B-end speed and direction of rotation are determined by the servo valve which controls input and exhaust pressures.

SERVO VALVE.—A valve block attached to the B-end contains an electro hydraulic servo valve, (figure 10-25). The servo valve uses an electric signal from the fuze setter amplifier to control hydraulic pressure to the motor. The servo valve opens and closes hydraulic fluid parts leading to the motor. Flexible hydraulic hoses (figure 10-25) connect the servo valve block and motor manifold to the flow control valve manifold.

Actuating Mechanism

The fuze setter actuating mechanism (figure 10-25) consists of a solenoid housing and valve block. The mechanism is mounted on the slide in front of the fuze setter (figure 10-23). A mechanical linkage connects the fuze setter assembly to the actuating mechanism (figure 10-25). The solenoid housing contains two-position, mechanically detented solenoids. The valve block contains a fuze pot operating piston and


SOLENOID HOUSING
FILTER
FLEXIBLE HOSES
VALVE BLOCK
FLOW CONTROL VALVE MANIFOLD
FUZE POT
LINKAGE TO ACTUATING MECHANISM
SOLENOID HOUSING
HOUSING
FUSE SETTER ASSEMBLY
SERVO VALVE
B-END
ACTUATING MECHANISM
VALVE BLOCK

53.310
Figure 10-25.— Fuze setter components.

a directional selector valve. The directional selector valve controls the porting of fluid to the fuze pot operating piston. The fuze pot operating piston extends or retracts the fuze setter.

Flow Control Valve Manifold

The flow control valve manifold (figure 10-25) directs hydraulic pressures to the servo valves of the right and left fuze setters. The flow control valve manifold is common to both fuze setters. Two solenoids mounted in solenoid housings operate valves which port hydraulic pressures to the fuze setter assemblies. Two flow control valves mounted in a valve block limit the volume of fluid that flows to their respective fuze setters. A single cylindrical bowl and filter element filters hydraulic fluid for the fuze setter servo valve and B-end.

Fuze Setter Amplifier

Each fuze setter has a solidstate electronic amplifier (servo amplifier) located in the EP 2 panel. The servo amplifier contains six module boards (three for each fuze setter), a synchro order transformer, a step down transformer, and a fuze setter fuse mounted below the servo amplifier (figure 10-24).

Functional Description

Fuze setting consists of four distinct operations; in order, they are: extend, index, fuze set, and retract. When a round is in the transfer tray and a fuze order is given, the fuze setter actuating mechanism extends the fuze setter assembly on to the projectile. An indexing order rotates the pawls to ensure their engagement with slots on the projectile fuze. When the pawls have turned a predetermined number of revolutions (2 1/3 turns), a fuze order position the pawls to the desired fuze setting. After the fuze is set, the actuating mechanism retracts the fuze setter assembly away from the projectile.

Fuze orders are either local or remote. The remote order signals originate from the fire control computer, and local orders originate from two stationary control transmitters (CX) in the EP 2 panel. The primary mode of fuze setter control is remote. Remote control order signals determine the fuze set time. The local order signal which is a "Safe" order synchro signal from CXs in the EP 2 panel is transmitted to the fuze setter when the right and left fuze setter select switch on the EP 2 panel is positioned to Safe. A "Test" order signal generated by a dummy director is applied through a test plug connection at the EP 2 panel when the fuze setter select switches are positioned to test. Remote order signals are applied to the fuze setters when the fuze select switch is set to "Run."

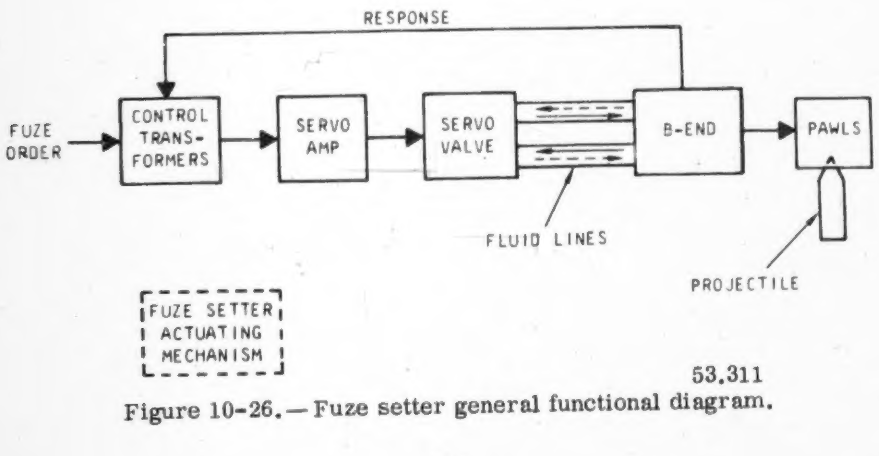
In remote operation, fuze order signals are applied to a one-speed control transformer (1 X CT), a five-speed control differential transmitter (5 X CDX). The one speed CT generates the coarse error signal. Its rotor is conventionally driven by a response from the fuze setter's hydraulic motor output. Coarse response also drives a d-c tachometer generator which provides the indexing complete signal to the servoamplifier. The fine order signal is first applied to the five-speed CDX. This synchro's rotor is driven by a response from the fuze setter's holding pawl and, therefore, modifies the fine order signal to the position of the holding slot in the projectile's fuze. After modification, the order signal is applied to the five-speed CT, generating the fine error signal. This CT's rotor is driven by a response from the fuze setter's indexing pawl.

The error signal (voltage) is applied to the fuze setter's servo amplifiers where it is processed and then applied to the electrohydraulic servo valve, figure 10-26. The servo valve controls the flow of hydraulic fluid to the B-end motor. As the motor turns, it drives the fuze setter pawls to set the fuze. A response loop geared to the synchros cancel the input error to the servo amplifier when the fuze reaches the desired setting.

The fuze-setting systems you have studied here are, as of this writing, the most widely used in the fleet today. Other systems, such as those found in turrets, operate with similar principles and have similar components; the major difference being the methods of operation and control.

SAFETY

Safety precautions issued by Naval Ordnance System Command and such supplementary safety precautions promulgated in NAVORD OP's related



53.311

Figure 10-26.—Fuze setter general functional diagram.

to ammunition and ammunition handling equipment must be observed. The following ordnance safety precautions are of a general nature, for special precautions for a specific type of ordnance equipment reference should be made to appropriate system OP's.

Modifications to ordnance handling equipment shall not be made without approval of the Naval Ordnance Systems Command (NAVORDSYSCOM). Requests or recommendations for modifications will be addressed to NAVORDSYSCOM and will include

1. Complete details of the proposed modifications including photographs, drawings, and engineering data as may be necessary.
2. Reasons for the modifications and improvement expected to result from the proposed modification.

Whenever any item of equipment associated with an ordnance installation or weapon system has undergone overhaul or major repairs, the equipment shall be tested to insure satisfactory and safe operation prior to operational use. Such tests shall include checks for proper operation and adjustment of safety devices.

Use safety devices provided for the gun system as designated. Keep the safety devices operative and in good order at all times. Inspect all safety devices frequently.

If safety devices are rendered temporarily inoperative on approval of competent authority, use signs or other appropriate means to warn personnel. Do not secure inoperative safety devices. Do not alter safety devices except by direction of NAVORDSYSCOM.

Do not operate equipment without ensuring that all personnel are clear of moving equipment.

Post ordnance safety precautions in appropriate locations and place conspicuous warning signs at danger points. Use NAVORDSYSCOM safety precautions signs in accordance with current instructions.

No Gunner's Mate should be without a complete knowledge of the general ordnance safety precautions listed in United States Navy Ordnance Safety Precautions, OP 3347. The safety precautions listed OP 3347 apply specifically to explosive and nonexplosive ordnance material and equipment located both ashore and afloat in facilities and units of the U.S. Navy.

CHAPTER 11

AMMUNITION HANDLING AND STOWAGE

According to OP 4, the term ammunition "includes all components and any and all explosives in any case or contrivance which is prepared to form a charge, complete round, or cartridge for small arms, rifle, gun, cannon, or for any other weapon, or for explosive-actuated device, impulse device, torpedo warhead, mine, bomb, depth charge, demolition charge, fuze, detonator, projectile, rocket, or guided missile." Ammunition includes all solid propellants as well as all hypergolic liquid propellant systems and other hazardous materials applied to ordnance uses and/or requiring surveillance for reasons of explosive safety. It also includes all Jatos, boosters, sustainers, military pyrotechnics, and offensive type chemical warfare materials.

As you can readily see, this covers a very large field—any and all parts of which you, as a chief or first class gunner's mate, will be expected to safely handle, stow, and maintain whenever the occasion should demand.

The instructions pertaining to the handling and storage of ammunition prescribed in this chapter are of a general nature only, but shall be strictly observed where applicable by all naval activities afloat and ashore. It is difficult to cover every possible emergency which may arise and which, if improperly handled, may have serious results.

Understanding all safety instructions and safety precautions listed in OP 3347, Ordnance Safety Precautions; OP 4, Ammunition Afloat; and OP 5, Ammunition Ashore, will make you able to grasp the ideas on which safety precautions and instructions are based. Accordingly, under circumstances not covered in ordnance publications at the time of an emergency, you may instinctively take the proper action.

As a leading Gunner's Mate, your duties will be to prepare and implement ammunition loading and stowage plans, to organize and administer a program of safety instructions, and to supervise crews in procedures for transferring, handling, and stowage of rockets, gun ammunition, mines ashore, missiles and nuclear weapons. Additional instructions for guidance in ammunition handling can be found in various ordnance instructions and publications or they are furnished by NAVORD.

All ordnance safety precautions are explicit and allow no leeway. Whenever ammunition or explosives are being received, transferred, stored, or prepared, the paramount consideration shall always be Safety and Reliability. The work on ammunition and explosives shall never be treated as a competitive evolution in regard to speed or methods.

ALLOWANCE LISTS

The Naval Ordnance Systems Command (NAVORDSYSCOM) ensures promulgation of the allowances of ammunition established by the Chief of Naval Operations. This is done by utilizing NAVORD Ammunition Allowance Lists (30,000 series) and NAVORD Instructions, which establish the full allowances. The source of supply for the NAVORD Ammunition Allowance Lists is Ships Parts Control Center (SPCC Code 730), Mechanicsburg, Pennsylvania.

Copies of NAVORD Instructions for ammunition allowances may be obtained from COMNAVDIST WASH DC (Supply and Fiscal Department-Code 514.3) Washington Navy Yard, Washington, D.C. 20390.

Generally speaking, there are two ammunition allowances for each ship. One is the regular service allowance which is required for combat readiness; the other is that portion of the full load which is expended yearly in training. Remember that CNO establishes a ship's full load allowance (including target ammunition) when the ship is initially outfitted.

SERVICE AMMUNITION ALLOWANCES

A NAVORD Ammunition Allowance List in the 30,000 series is issued to each vessel in active service listing the full war allowance of ammunition which is authorized for that particular ship. Another NAVORD Ammunition Allowance List, also in the 30,000 series, is issued to certain ships such as aircraft carriers, ammunition ships, and various others listing the prescribed types and amounts of ammunition which that ship is required to carry as a "Fleet Issue/Cargo Load." This is to be carried in addition to the regular service allowance.

Cognizant fleet, force, and type commanders may authorize temporary deviations from these allowances whenever it is necessary to meet scheduled or anticipated operations. However, requests for major revisions of NAVORD Ammunition Allowance Lists should be directed to the Chief of Naval Operations, via the appropriate chain of command and NAVORDSYSCOM Headquarters, while requests for minor changes or substitutions of types should be forwarded directly to NAVORDSYSCOM.

TRAINING AMMUNITION ALLOWANCES

The training ammunition allowances for all phases of active fleet training as established by the CNO are promulgated in the NAVORD Inst., 8011 series. These instructions set forth the various training allowances for each year and remain in effect until modified or cancelled. Allowances as prescribed are for the purposes and periods as specified only. Any unexpended allowance at the termination of a specific cruise or fiscal year, as appropriate, is automatically cancelled.

Should an augmentation of the allowance of a specific type, or types, of training ammunition be desired, a request may be made to the cognizant Fleet or Type Commander. Requests for special allowances in excess of regular training allowances, and requests for permanent modifications of training allowances should be addressed to the CNO via the appropriate chain of command and NAVORDSYSCOM.

For precommissioning and shakedown training of newly commissioned or reactivated ships, a combined special allowance equal to the annual training allowance of the ship is authorized. A special allowance equal to 50% of the annual training allowance is authorized for shakedown training of ships which have undergone armament changes.

Ammunition allowance, both service and training, constitute the necessary authority for the requesting of ammunition from ammunition facilities. Care must be taken to ensure that all requested ammunition conforms with space, weight, stability, and immersion limits prescribed by NAVSHIPSYSCOM and the limiting weight of ammunition as specified in the Ship's Ordnance Equipment List. Also, the cumulative total of training ammunition requested must not exceed the annual allowance.

Further information on requesting ammunition will be given in chapter 13.

POLICIES GOVERNING ISSUE OF AMMUNITION

Following are some of the things you may encounter when your ammunition is delivered or received, which may or may not be in agreement with the exact quantities as specified in the ammunition invoices.

Ammunition activities will issue ammunition and ammunition details to the nearest full container approximating the original order, request, or allowance. No notice will be given other than to indicate the exact quantities issued or received on the appropriate shipping documents, invoices, and so forth.

Transfers to an issuing activity for stock (i.e., tenders) or overseas shipments (i.e., AEs) will not include partially filled containers.

Authority for shipment of unserviceable, obsolete, or restricted ammunition or explosives for disposition will be the exact amounts as specified by NAVORDSYSCOM.

Specifically, the above outlined policy is subject to the following provisions.

GUN AMMUNITION

Dummy drill ammunition, and ammunition for structural test firing will be issued in the exact amounts ordered or requested.

Items of ammunition, of which the ship's maximum allowance constitutes a small fraction of a container (i.e., primers and fuzes), will be issued in the amounts as specified as appropriate orders, requests, or allowance lists.

BOMBS

Bomb fuzes that are procured from the Army and are packed 25 or more to a wooden box will be supplied in the amount requested unless a full wooded box would not exceed the amount requested by more than 5 units. All fuzes packed less than 25 per wooden box will be issued in the exact quantities requested.

Spare primer detonators that are packed 100 to a wooden box will be issued to the nearest inner container (comprising 25 units).

Arming-wire assemblies (including safety clips) will be issued in the amounts requested up to the quantity of 40. In quantities over 40, assemblies will be furnished to the nearest even container of 50 or 100 assemblies as appropriate.

Components for inert bombs and inert fuzes will be supplied in the amount requested.

OTHER TYPES OF AMMUNITION

Orders, requests, or authorized allowances for SMALL ARMS AMMUNITION that involve less than two full boxes will be issued or shipped to the nearest full cardboard carton. Larger quantities will be issued to the nearest full shipping box.

When issued to tenders for cargo ammunition, PYROTECHNICS AND CHEMICALS should be adjusted where necessary to include only full containers. However, when issued for the purpose of ship's allowance, they must be supplied in the exact amounts specified, with the exception of two-star cartridges and Very cartridges, which may be issued to the nearest metal or cardboard inner container. When two or more colors of the same type of signal are specified, other than those mentioned above, they should be repacked together to make full boxes where possible. Such boxes must be clearly marked as to the colors repacked in them.

Issues of small quantities of chemical warfare material to fill training allowances will be made in exact quantities. Various chemical grenades may be repacked together but such boxes must also be clearly marked as to the mixed contents.

ROCKET FINS AND FUZES will be issued or shipped to the nearest next full container.

Where MIXED PACKING is established, such packing must comply with the rules of compatability.

GENERAL REGULATIONS FOR HANDLING AMMUNITION

OP 4 states: "Instructions for the handling of ammunition and explosives in port areas within the confines of Naval Districts are established and promulgated by the Chief of Naval Operations."

During peacetime, the hazards involved in handling large quantities of ammunition are considered too great at places other than those specifically designed for these operations. There are two types of locations where loading and off-loading of large amounts of ammunition are authorized.

1. Certain ammunition activities with appropriate piers have been designated by NAVORD as "ordnance facilities" for the issue, loading and unloading, and receipt of ammunition to and also available for these functions.
2. Certain berths or areas, indicated on applicable harbor charts as "explosives berths" or "explosives anchorages", have been designated by the Corps of Engineers, Department of the Army, as authorized for use by vessels for loading and off-loading of ammunition.

To conform with local safety requirements and restrictions, the general instructions issued by the Chief of Naval Operations may be further amplified or detailed by the cognizant naval districts, by "ordnance facilities," and by other proper authority.

Exceptions

Where the characteristics of a vessel preclude the use of an ordnance facility or an explosives berth, or none are available, naval districts may designate other locations where loading or unloading of ammunition can be accomplished. This exception applies only to the following types of ammunition and, where specified, within the limits of size or quantity:

Small Arms, Rockets (5 inch and smaller), Gun and Mortar; Grenades; Chemical (except lethal toxic), Fuzes, Primers, Detonators; Pyrotechnics; Impulse, Blank, Saluting Charges; Smoke Mixtures (liquid FS and FM), JATO Units for aircraft takeoff, and JATO igniters (not to exceed 20 of each).

Certain other locations may be designated by the Chief of Naval Operations where small quantities of ammunition may be transferred to and from ships under conditions prescribed by naval districts. This exception applies generally to the transfer of ammunition required for tests, training, and saluting, and the minor replenishment of other types of ammunition. When operations at piers under the two exceptions above are authorized, ammunition must not be off-loaded from a ship until transportation is available to remove it promptly, nor will it be transported to the pier for loading until the ship is ready to receive it.

Responsibility for Proper Handling

The general areas of authority and responsibility in the case of a ship berthed within the jurisdiction of an ordnance facility are set forth by Article 1325, U.S. Navy Regulations, 1948. No attempt will be made in this book to cover all existing safety precautions. However, some of those pertaining to safety in connection with the transfer of ammunition are as follows.

The commanding officer of the vessel has direct responsibility for compliance with all safety regulations "within the ship" while it is at a pier or dock or in adjacent waters as defined by local regulations. Ammunition or explosives are considered as "within the ship" when their weight is carried in whole or in part by the ship.

No emergency drill requiring the use of the general alarm, ship's bell, whistle, or siren should be held on board ship during ammunition or explosives handling operations while alongside an ammunition or explosives pier as such action might lead to misunderstanding.

In the event of an emergency, and upon the appropriate signal from qualified personnel, all operations involving ammunition or explosives MUST stop instantly.

All firemains on board a ship actually engaged in loading or discharging operations should be inspected to ensure efficient functioning. Firehoses will be broken out and ready for use. The firehose valves controlling the hoses should remain "cracked open" (except in freezing weather) so that casual observation may indicate that water is available.

GENERAL INSTRUCTIONS

In addition to the general and other instructions in this book, the applicable safety precautions of OP 3347, United States Ordnance Safety Precautions, should be thoroughly understood by all personnel concerned with the handling of ammunition and explosives.

Care Required

There is no purpose in requiring exactness of detail in the preparation, overhaul, and assembly of ammunition to ensure its proper functioning unless it is subsequently handled, stored, and shipped in such manner as to preserve and maintain it in perfect condition to serve the purpose for which it was intended. Improper, rough, and careless handling of ammunition, ammunition components, and ammunition details may result not only in malfunctioning but, of greater importance, may cause accidents which result in damage or loss of life. The history of accidents which have occurred in the use, handling, shipping, and stowage of ammunition shows that, in practically every instance where the cause could be determined, the accidents have been due to circumstances which were avoidable. Many of these examples and case histories are contained in OP 1014, Ordnance Safety Precautions, Their Origin and Necessity.

Any repeated work, no matter how dangerous, is likely to become routine and lead to carelessness. Therefore, constant vigilance and intelligent close supervision must be maintained to prevent accidents in operations involving ammunition and explosives.

Utmost care must be exercised when handling all kinds of explosives, ammunition, ammunition components, and ammunition details. This pertains to all officers and other persons connected with the naval service.

Handling of ammunition MUST never take place during fueling operations or when loading flammable stores. Except in case of emergency, ammunition shall not be transferred during fueling operations ashore. This paragraph does not restrict simultaneous transfer of fuel and ammunition during underway replenishment at sea.

SUPERVISION OF PERSONNEL AND EQUIPMENT

Whenever ammunition or explosives are being received, transferred, or stored, the work should be supervised by an officer or petty officer who is thoroughly familiar with the rules for care and handling of explosives. He must make sure that all persons engaged in the work are properly impressed with the necessity for exercising the greatest care.

Personnel Requirements

Personnel engaged in ammunition and explosives operations should be limited to the number necessary for the safe and efficient performance of the work at hand. However, a sufficient number should be employed to ensure safe handling and to ensure a steady flow of ammunition without undue concentration at any point.

Personnel assigned to ammunition and explosives operations should be adequately trained in this type of work. All operators of mechanical handling equipment such as cranes, winches, and booms must be specifically qualified to operate the equipment to which they are assigned.

Equipment Requirements

The following regulations apply to equipment used for moving explosives and ammunition. You should refer to OP 2173, Handling Equipment for Ammunition and Explosives, for a detailed study on the handling equipment.

TYPES AND AMOUNT OF EQUIPMENT.—OP 4 states that handling operations must never be started until adequate equipment is available. An ammunition activity will provide required portable equipment for use by a ship upon request.

Approved special handling equipment for a special type of ammunition, such as projectile carriers and bomb trailers, is to be used whenever this equipment is available.

Slings used for handling ammunition and explosives must be of all-rope or of all-wire construction, never a combination of the two.

CONDITION OF EQUIPMENT. — Handling equipment such as trucks, trailers, railroad cars, elevators, industrial trucks, cranes, winches, conveyors, hoists, slings, bands, lifts, whips, skip boxes, pallets, salmon boards, nets, pie plates, skids, cradles, adaptors, bomb carriers, rocket carriers, mine-handling accessories, projectile carriers, and tongs must be properly maintained and frequently inspected to ensure that they are in safe working condition and of adequate capacity to safely serve the purpose for which they are being used. These inspections should be made just prior to, and frequently during, loading and off-loading operations.

All electrical equipment such as winches and motors should be inspected by a qualified electrician prior to use and frequently during the operation.

Brakes and controllers of hoisting motors must be in efficient operating condition, and hoisting speeds regulated so that there will be no danger of jams or parting of lines.

Shipboard slings, crane cables, and boom cables should be tested periodically for operating strength in accordance with the requirements of the cognizant bureau.

Protruding nails or similar sharp metal, loose powder or other combustible material, or unauthorized flame-producing devices are strictly prohibited on transportation equipment.

Responsibility for the operating condition of handling and transportation equipment will rest with the ship and ordnance facility for their respective material.

Equipment that shows signs of weakness or undue wear is to be rejected.

USE OF HANDLING EQUIPMENT TO LIMIT DAMAGE.—Handling equipment should never be loaded to the limit of its maximum rated capacity.

All gang planks, gang boards, ramps, bridge plates, skids, and similar equipment must have sideboards or rails. They must be of sufficient strength to carry the imposed load.

Explosives or hazardous materials, whether in containers, in bulk, or loaded into projectiles, cartridges, or ammunition components, must be handled carefully to prevent shock or friction which may cause a fire, and explosion or damage. These materials must not be thrown, dropped, or tumbled over the deck or over other containers, or dragged or pushed along the deck.

During the handling of explosives and ammunition every precaution must be taken to avoid their contact with sand, earth, gravel, or other abrasive or spark-producing substances.

Ammunition and explosives containers must be hoisted and lowered steadily and slowly, and landed gently on a cushion of mats or old mattresses to prevent damage. Such cushions are not required when handling palletized material. Ample time will be allowed for proper removal of a hoist after the landing.

LOADING/OFF-LOADING PLAN

Prior to loading or off-loading any ammunition, other than in the case of small amounts which will be handled by qualified weapons personnel, a workable ammunition handling plan should be outlined and promulgated in the form of a Weapons Department Notice. The Ship's Organization Manual may include a standard loading and off-loading plan. If not, you can most assuredly find a precedent in your weapons department files of instructions and notices. This plan can be used as a guideline but will undoubtedly have to be altered to meet present circumstances.

Your loading plan should include the following information:

1. A sketch or drawing showing the positions of all stations where ammunition will be taken aboard and, if the ship is to be at an anchorage, the positions that all barges, camels, cranes, and associated equipment will take alongside the ship.
2. The types and amounts of ammunition to be taken aboard at each station.
3. A clear description of the route that each type of ammunition will take from the onload station to the magazine.
4. A list of personnel assigned to each station, providing for rotation, chow relief, and change of station upon completion of comparatively short assignments.
5. A list of the ammunition handling equipment to be supplied at each station by the ship. This equipment must be thoroughly inspected before the operation.
6. A list of the ammunition handling equipment to be supplied by the ammunition facility, or other, and where it will be required. This will include such equipment as cranes, conveyor belts, bomb trucks, and electric fork lifts.
7. Smoking areas (if any) should be defined.
8. All pertinent SAFETY PRECAUTIONS must be listed.
9. A list of the types and amounts of ammunition to be loaded into each separate magazine. (A loading plan for each magazine should be given to the officer or petty officer in charge of its stowing.)

Besides these, depending on the circumstances, you may well find other important items to add to your loading plan. An off-loading plan would include much the same information as that in the loading plan, except, of course, that routings and other particulars would be quite different.

Ensure that all persons in a supervisory capacity receive a copy of this plan. If at all possible, supervising petty officers should be assigned to stations where men of their own division are working. This will prove especially helpful should it become necessary to shift large groups to another station during the operation.

INSPECTION BEFORE ACCEPTING

Prior to acceptance of a shipment of ammunition and explosives, a ship's representative will inspect, in company with an ordnance facility representative (the supervisor in case of a loaded lighter), the seals of the vehicle and check the general condition of the shipment, and make particular check of the following.

1. See that the material is properly boxed in correct shipping containers. See that there are no leaky containers, and that none are broken or so weak as to break during transportation. In case leaky containers or other damaged materials are being turned into an ammunition activity, see that they are plainly marked and segregated insofar as practicable from other material.
2. See that the total quantity shipped is in agreement with that invoiced (if feasible at this time).
3. See that the material is properly stored or stacked and braced in the vehicle to prevent damage to containers or contents and in accordance with applicable regulations.
4. A red flag shall be prominently displayed during daylight and a red light at night by (1) all boats, lighters, and other craft while loaded with or transporting explosives or ammunition; (2) tugs towing lighters or barges which are transporting explosives or ammunition; and (3) all vessels, barges, lighters, or boats engaged in loading or off-loading explosives or ammunition.

OPERATION AT NIGHT

Live ammunition and explosives should not be loaded on or discharged from a ship or lighter at night except in an emergency or when required by the vessel's sailing schedule, or as authorized by NAVORDSYSCOM. Piers must be adequately lighted and equipped with fire protection and safety equipment. If loading or unloading is not completed during the day, proper precautions must be taken to guard and protect against fire, and a sufficient crew should be on hand to adequately cope with emergencies that might arise. If night operations are required, only carefully placed, approved electric lights, portable lanterns, or flashlights will be used inside the ship, or lighter, or in the adjacent areas.

Lighting equipment must meet the standards of the National Electric Code as follows:

1. Extension lights must be fitted with exterior globes and stout guards to protect the bulbs.
2. Wire leading to the lights must be sound and heavily insulated and show no evidence of being likely to short circuit.
3. Extension lights should be suspended in such a manner that no strain is carried by the light cable; they are not to be suspended by the cable.
4. Extension lights must be so guarded and protected that neither the light nor the light cable will be in contact with any metal part of the ship, lighter, vehicle, handling equipment, or with any of the ammunition, explosives, or their containers.
5. Extension lights must have an outside power source not connected in any way to the lighter, railroad car, truck, or vehicle.

METHODS OF HANDLING

Handling of ammunition MUST be reduced to the minimum in order to prevent damage to containers, torn powder bag charges, damage to tanks, cartridge cases, and bomb and rocket fins, loosening of projectiles, and to reduce chances of accidents.

Precautions to be Observed

The precautions for moving projectiles, powder, cartridge tanks, and containers are covered in OP 3347, Ordnance Safety Precautions, and will not be repeated here. However, for the protection of ammunition during handling you must MAINTAIN AIRTIGHT INTEGRITY, and handle bulk explosives and ammunition so as to avoid rupture of the containers and prevent undue friction between them. Should a container be found to be unsatisfactory, it must be removed to a suitable location and its contents shifted to another container, which is in good condition. Remember to relabel as necessary.

Avoid sparks, flame, and direct rays of the sun when handling ammunition and explosives. These materials MUST NOT be unnecessarily exposed to the direct rays of the sun and, when prolonged exposure is anticipated, protective covering should be provided before handling operations are started. Matches or other flame—producing articles MUST NEVER be permitted in the vicinity of explosives and ammunition, and particular attention must be given to avoid making sparks from the contact of steel on steel. Personnel working with such materials MUST NOT have any iron, steel or articles of a combustible nature about their person.

Avoid contact with water. Ammunition and explosives and their containers should be protected at all times from water and dampness to prevent corrosion of metal parts. Water and dampness may also have adverse effects, possible hazardous, on the properties of propellants and explosives.

Special Precautions for Bomb Type Ammunition

Bomb type ammunition, which includes aircraft bombs, mines, warheads, depth charges, and certain types of rocket heads and projector charges, and which are characterized by a large high explosive charge-to-weight ratio, is particularly susceptible to "container-dent-sensitivity" because its thin walls are relatively easily ruptured or dented. Denting of thin walls of a thin container by impact has caused partial or complete detonation. A certain degree of confinement combined with local heating of the contained explosive by a particular kind of impact has been known to cause instantaneous explosive action.

Whenever bomb type ammunition is transferred from one activity to another, the issuing activity should mark, prior to any transfer operation, each dent, however slight, with a white painted circle. This will indicate to the receiving activity any additional dents which may have been caused during the particular transfer operation and provide irrefutable evidence of rough and potentially dangerous handling. The receiving activity will report in full details, with photographs where possible, all instances where bomb type ammunition is received with uncircled dents. This report will be forwarded to NAVORDSYSCOM and a copy provided to the activity from which the ammunition was received.

Hazards of Electromagnetic Radiation to Ordnance (HERO)

NAVORD OP 3565 shall be used by all commands as a guide in handling and storing ordnance items containing electroexplosive devices which may be affected by electromagnetic radiation. The manual outlines detailed requirements, procedures, and restrictions prescribed for handling many ordnance items and general restrictions applicable to all ordnance items containing electroexplosive devices.

Electroexplosive Device (EED) is any single discrete unit, device, or subassembly whose actuation is caused by the application of electric energy which in turn initiates an explosive, propellant, or pyrotechnic material contained therein. The term electroexplosive device does not include complete assemblies which have electric initiators as subassemblies, but includes only subassemblies themselves. The term is synonymous with electric initiator.

To ensure the HERO safety and HERO reliability of ordnance systems, NAVORDSYSCOM sponsors an extensive testing program to determine their susceptibility to rf (radio) energy. These tests are conducted in the maximum rf environmental levels to which the ordnance may be exposed under actual handling and loading conditions. Three HERO classifications for ordnance items have been established.

"HERO SAFE ORDNANCE." — Any ordnance item that is sufficiently shielded or otherwise so protected that all EEDs contained by the item are immune to adverse effects (safety or reliability) when the item is employed in its expected shipboard rf environments, provided that the General HERO Requirements are observed.

"HERO SUSCEPTIBLE ORDNANCE SYSTEM." — Any ordnance system proven (by tests) to contain EEDs that can be adversely affected by rf energy to the point that the safety and/or reliability of the system is in jeopardy when the system is employed in expected shipboard rf environments.

"HERO UNSAFE ORDNANCE." — Any ordnance item is defined as being "HERO UNSAFE" when its internal wiring is physically exposed; when tests are being conducted on the item that result in additional electrical connections to the item; when EEDs having exposed wire leads are present, handled, or loaded; or when the item is being assembled or disassembled; or when it is in a disassembled condition. Ordnance items that fall into the above classification may be exempted from being classified as "HERO UNSAFE ORDNANCE" as the result of HERO tests conducted to determine specific susceptibility.

During ordnance transfer, ensure that positive notification of weapons condition (HERO Unsafe Ordnance and HERO Susceptible Ordnance Systems) is given whenever such items are transferred from one ship or station to another. HERO unsafe ordnance shall not be handled in rf field intensities that exceed those listed in OP 3565, Technical Manual RF Hazards, Personnel and Fuel.

AMMUNITION STOWAGE ABOARD SHIP

MAGAZINES are the detailed specifications for construction of the U.S. Navy ships and individual ship's blueprints developed by Naval Ship Systems Command and approved by NAVORDSYSCOM establish and designate ammunition stowage spaces for various ship types and classes and modifications. Where aircraft carriers or aircraft are involved, ammunition stowage spaces shall also be satisfactory to NAVAIRSYSCOM. Magazines are arranged with regard to facility of supply, the best obtainable protection, and the most favorable storage conditions. Various categories of explosives and ammunition normally are stored in separate magazines or lockers so that the highest possible degree of safety is obtained. Stowages vary considerably with the type of ship, the space available, and the amounts of explosive involved. All magazines are marked by appropriate label plates designating the compartment and the types of ammunition to be stowed therein; i.e., powder magazines, and detonator lockers. Primary and missile magazines are designed to hold a ship's complete allowance of ammunition for training and peacetime operations. Ready-service magazines may be used to stow additional ammunition to fill a ship's wartime allowance. Changes in ammunition or allowances for any other reason shall be referred to NAVORDSYSCOM for approval. No alterations to magazines shall be made without approval from NAVORDSYSCOM and NAVSHIPSYSCOM. Unsatisfactory storage conditions and magazines which do not comply with NAVORD OP 3347 and other applicable instructions shall be reported to NAVORDSYSCOM with a request for instructions to correct the deficiencies.

TYPES OF MAGAZINES

There are many different types of magazines provided on ships. Each magazine is designed specifically for the type of ammunition it is to contain. The magazine types include primary, missile, ready-service, lockers, and biological and chemical.

Primary Magazines

Primary magazines are stowage spaces that usually are located below decks and, if possible, below the water line. They are adequately equipped with thermal insulation, ventilation, and sprinkling systems and they can be securely locked.

Missile Magazines

Because of the nature of guided missiles, requirements for their stowage aboard ship differs from the conventional ammunition magazine requirements. Surface-launched missile magazines usually are located above the water line while air-launched missile magazines in aircraft carriers usually are located below the water line and within the armor box. Air-launched missile ready-service magazines may be located above the water line or within the armor box. Missile magazines contain electrical, hydraulic, and pneumatic power operated handling equipment. Restraining gear is provided to prevent movement of an inadvertently ignited motor. To provide adequate and continuous surveillance in magazines containing certain missiles and to provide assurance that a specific hazard is not actively present, these magazines are equipped with specialized detection equipment. Special care is taken with the vent system of missile magazines to ensure that magazine pressures do not build up to a dangerous level if a missile motor is ignited. A plenum vent and or a relief port is provided for this purpose. Additional fire fighting equipment is frequently provided for missile magazines. It may consist of carbon dioxide, foam, water injection, or a sprinkling system or a combination of these systems.

Ready-Service Magazines

Ready-service magazines are designated spaces located near the weapon or area to be served which provide permanent stowage for part of the ammunition allowance. They normally are equipped with thermal insulation, ventilation, and a sprinkling system and they can be securely locked. Some missile magazines, containing automatic handling equipment, are ready-service magazines. Certain magazines located in the armor box of aircraft carriers and used for stowage of complete, assembled rounds of weapons and deployable targets also are ready-service magazines. Changes in a ship's assigned armament may result in overall increases in the required magazine space with resultant adaptation of ready-service magazines for use as primary magazines. Such adaptation, when accomplished, shall include as many primary magazine characteristics as possible. Ready-service stowage denotes the ammunition storage facilities in the immediate vicinity of the weapon or space to be served, such as weather deck lockers, bulward racks, and upper handling rooms. This stowage is used only when the ammunition actually is required to service the weapon and then the amount so stowed should be kept to a minimum except for weapons authorized for storage in the all-up condition. Ammunition is subject to more rapid deterioration when it is in ready-service stowage and must be examined closely before being returned to magazines. If ammunition is returned to a magazine from ready-service stowage, it shall be segregated and fired first at the next authorized firing. Locking facilities for ready-service storage are not required if the primary magazines are adequate to stow the ready-service ammunition when a watch is not maintained at the guns and in the ready-service stowage areas.

Lockers

Certain compartments or lockers are provided for stowage of special types of ammunition and ammunition components such as detonators, pyrotechnics, and chemicals. They frequently are located on the weather deck and are as convenient to the weapon or space to be served as possible. They may or may not be equipped with sprinklers, but they are provided with locking facilities. Special flare ready-service lockers are located at outboard locations on carriers for short-term storage of aircraft parachute flares that have been removed from primary pyrotechnics magazines and prepared for launching or returned from a mission not launched. These lockers can be jettisoned automatically in case of accidental flare ignition.

Biological and Chemical (B/C) Magazines

B/C ammunition classified as lethal or incapacitating will not be carried aboard ship unless specifically authorized by NAVORDSYSCOM or higher authority. If authorized, specific instructions will be issued by NAVORDSYSCOM and trained personnel will be required. Specific spaces aboard ship may be designated as B/C magazines by NAVSHIPSYSCOM. Decks and bulkheads of B/C magazines shall be coated with an impermeable material and the magazine shall have provision for sampling the atmosphere of the magazine from another compartment. Facilities for personnel and gross decontamination shall be provided near the magazine.

DESIGNATION OF MAGAZINES

Magazines or ammunition spaces afloat are designated with particular reference to the purpose intended. Insofar as practicable, magazines are designated to hold a single type of ammunition.

Single-Purpose Magazine

The following designations are given for magazines whenever a single-purpose stowage is practical: powder and rocket motor magazines; fixed ammunition magazines; small arms magazines; missile magazines; warhead lockers or magazines; aircraft bomb magazines; projectile and rocket head magazines; fuze magazines; detonator lockers; pyrotechnic magazines or lockers; ready-service ammunition rooms, boxes, racks, or lockers; and biological and chemical (B/C magazines). While stowage of a single type of ammunition in individual magazines is desirable, it is not always possible. NAVORDSYSCOM has authorized certain mixed stowages in magazines that retain single-purpose designations.

Multipurpose Magazines

Where stowage space is limited and the mission requires carrying various types of ammunition, stowage of more than one type of ammunition in one magazine is an acceptable hazard. Authorization for this type of storage is at the discretion of the operational commander. B/C weapons and pyrotechnics which have been removed from containers and fuzes and detonators which are not integral parts of, or assembled within, the ammunition shall not be stored in mixed stowage. Where mixed stowage is necessary, the various types of ammunition shall be segregated within the magazine and each type shall be suitably marked for ready identification. Ammunition may be segregated according to use. For example, all armor-piercing projectiles of one caliber will be in one group; all high capacity projectiles in another. When several indexes of powder or sizes of ammunition are stowed in the same magazine, the ammunition shall be segregated by indexes and sizes. Location of the various indexes of powder shall be posted within the magazine. When identical ammunition is to be stowed in several magazines, it shall be divided as equally as possible. The ammunition shall be stowed so that the oldest ammunition will be most accessible and used first and so that weapons of a battery may be readily supplied with any type of ammunition.

EQUIPMENT IN MAGAZINES

Magazines are fitted with temperature boards, brackets for tank wrenches, hooks for thermometers and buckets, shelves, eyebolts, and pad eyes as required by the ammunition they contain. The bearers of the lowest rows shall be high enough to allow cleaning under them. Portable fittings are permitted in aisles and passageways if handling space is adequate. Piping shall not be routed through magazines unless it is required for the magazine or unless no other routing is possible. Wood is acceptable for dunnage and sheathing in ships ammunition stowage spaces. Where metal dunnage is used it shall be electrically connected to the ship's hull.

TEMPERATURE CONTROL IN MAGAZINES

Insulation (Thermal)

Insulation shall be provided on the bulkheads (except divisional bulkheads) and decks of all smokeless powder and fuze magazines and the biological, chemical, pyrotechnic, and bomb magazines that are located near to sources of heat capable of providing temperatures of 110°F or more. Magazines on destroyers and smaller units normally are not insulated.

Ventilation

Magazine ventilation systems shall be operated as necessary to circulate fresh air and maintain temperatures below 100°F. The ventilation systems shall be stopped when necessary to prevent overheating or condensation of moisture. The system should be secured and the water-tight covers closed whenever ventilation is not required to maintain the temperature below 100° F. Frequently in hot climates magazines can be maintained at a lower average temperature by closing off the supply of air during the heat of the day and running the blowers only at night when cool air can be forced in. During the day the magazine will heat slowly by conduction rather than rapidly by forcing in air that is already heated. Once a specific procedure for a particular magazine or condition is determined, it should be made a matter of record for future guidance.

SUPPLY AND EXHAUST VENTILATION.—All magazines not fitted with mechanical cooling are provided with supply and exhaust ventilation. The supply ventilation ducts and the exhaust ventilation outlets to and from magazines are fitted with standard covers for maintaining watertightness and with wire-mesh screens which shall be kept clean and in good condition. During combat, the duct shall be closed to prevent the entrance of flame from hits on the ship unless there are imperative reasons for doing otherwise. Forced draft ventilation may be used to prevent excessive temperatures in uncooled handling rooms where there is considerable activity. Generally there is sufficient air volume in sealed magazines and handling rooms to provide a safe working atmosphere for approximately five hours. Inhalation of ether fumes resulting from the opening of powder tanks in a magazine will produce slight intoxication without appreciably reducing the work efficiency of most persons. Magazines should be ventilated or blown through after five hours of continuous occupancy.

SPRINKLING SYSTEMS

Magazines for powder, fixed ammunition, small arms ammunition, bomb-type ammunition, pyrotechnics, projectiles, rocket ammunition, and JATO units usually are fitted with sprinkling systems. Weather deck lockers for ammunition components and weather deck 40mm and 20mm ready-service ammunition rooms do not require sprinkling systems except when they are used in peacetime for stowage of saluting charges. Primary magazines, missile magazines, and ready-service magazines which are not readily accessible to firefighting personnel or which may be subject to general conflagration, such as those magazines adjacent to flight and hangar decks of aircraft carriers, shall be equipped with remotely controlled sprinkling systems. The sprinkling systems of bomb-type and pyrotechnic magazines must have the capacity to flood the magazine quickly in case of fire. As many magazines as possible shall be located below the water line to prevent loss of stability when flooded. Chapter 9930 of NAVSHIPS Technical Manual, NAVSHIPS 250-000, Volume III, contains a complete description of the firefighting equipment and procedures used for combating fires in ship magazines.

Types of Systems

Sprinkling systems may be classified by the type and location of the control exercised over the valves that restrain the flow of water. These valves may be operated manually (at the valve) or by remote control (manually or automatically). There are three types of remote operation: Manual, by operating gears; hydraulic, by means of control cocks and water from the fire system or control cocks and oil pressure supplied by hand pumps; and automatic, by means of a "rate of rise" or combined "rate of rise" and fixed temperature thermo-pneumatic control system.

Tests of Sprinkling Systems

Testing of the sprinkling hydraulic control system shall be conducted in accordance with NAVSHIPS Technical Manual, Chapter 9480 and testing of the sprinkling thermopneumatic control system shall be conducted in accordance with NAVSHIPS Instruction Book 348-0781 (0348-078-1004). All tests of magazine sprinkling system shall be reported to the commanding officer and entered in the ship's and Gunnery Department's logs. Entries should include all defects disclosed by the tests and any repairs made to the system. Magazines shall be inspected by competent personnel after all tests of sprinkler systems are completed, and all systems returned to normal to make sure that no valves are leaking and that no water has been inadvertently introduced into any magazine. Whenever sprinkling systems have been overhauled, a careful examination shall be made to see that all group-control valves have been tightly closed. Test castings are provided to isolate the dry piping to the magazines, thereby permitting routine tests of the operating condition of the group control valves to ensure that there is no obstruction to the flow of water and that the valves seat tightly. The castings and their plugs or fittings shall be secured in place before introducing water into the system. After overhaul or when a magazine has been painted, the dry sprinkling pipes shall be blown through with compressed air (5 p.s.i.) to ensure that the offices have not been painted over or clogged with dirt.

WORK LIMITATIONS AND SECURITY OF MAGAZINES

Before performing work which may cause abnormally high temperatures or intense local heat in magazines, magazine areas, or adjacent spaces, all explosives and ammunition MUST be moved to a safe stowage. This refers to work which requires use of cutting or welding torches and similar appliances in or near the magazine, and the steaming out of oil tanks and compartments.

Fuzing and unfuzing of bomb type and rocket ammunition MUST NOT be done in or near magazines. Detonators, boosters, primary detonators, or other fuzing mechanisms MUST NOT be assembled in bomb type ammunition in or near magazines.

In peacetime, all magazines, explosives lockers, sprinkling system controls, ready-service boxes and magazines ammunition hoists shall be kept closed and locked except when they are open for inspection, ventilation, testing, or authorized work. They shall be opened only when authorized by the officer in charge of the space, who shall be responsible for securing the locks upon completion of the operation. Magazine keys shall be kept by the commanding officer or an officer designated by him as custodian of magazine keys. Lighters, barges, railroad cars, trucks, and other conveyances containing ammunition or explosives shall be kept securely closed and locked or guarded except when required to be open for ventilating, cooling, inspection, or handling of the contents, in which case a specific person shall be directed to be in charge; he shall be responsible for the security of the contents and of the carrier.

In time of war and at the discretion of the commanding officer, magazines, explosives lockers, and ready-service lockers need not be secured with locks, but MUST be fully dogged closed. WATCH THIS DOGGING OF MAGAZINE DOORS AND HATCHES because personnel taking daily magazine temperatures may have the tendency to secure the doors and hatches with just a few loose dogs to permit easy access to the magazine during the next round of taking temperatures.

READY-SERVICE STOWAGE

Ammunition should not be stowed in ready-service stowage unless needed at the weapon, and then the amount so stowed must be kept to a minimum. Such ammunition is subject to rapid deterioration and must be specially examined before being returned to a magazine. If such ammunition is returned to a magazine, it must be segregated and fired first at the next authorized firing.

Protection from Exposure

Ammunition in ready-service stowage MUST be protected from the direct rays of the sun and from weather with suitable covering. Maximum and minimum thermometers will be placed in ALL ready-service boxes which contain ammunition, and the temperature must be recorded daily. Should the temperature of these boxes exceed 100°F, the following steps MUST be taken to effect artificial cooling.

1. Protect boxes from direct rays of the sun with awnings and screens.
2. Cover boxes with wet blankets or similar materials.
3. Maintain good circulation of air around the boxes to produce evaporation in the wet blankets.

Should any ammunition containing smokeless powder unavoidably be exposed to temperatures in excess of 110°F, a log of the temperatures and the number of hours so exposed must be maintained. If the ammunition remains in ready-service stowage exposed to temperatures in excess of 110°F, for a cumulative total of 500 hours, the procedure which MUST be followed is described later in the chapter. Should ammunition containing smokeless powder be exposed to temperatures in excess of 110°F for any period of time and then returned to the magazine, it MUST be segregated and issued first for firing and for further ready-service stowage. Any further exposure to temperatures in excess of 110°F will be added to the cumulative total and, when 500 hours of such exposure have occurred, the procedure described later must be followed.

REGULATIONS FOR STOWAGE OF AMMUNITION

The stowage regulations prescribed here (from OP 4) MUST be followed unless compelling reasons dictate otherwise, in which case the Chart of Permissible Stowages (OP 4) MUST be used in determining the types of ammunition which may be stowed together.

SMOKELESS POWDER

Smokeless powder charges are stowed in magazines separate from other types of ammunition; preferably each type and size of smokeless powder charge should be stowed in a separate magazine. The magazine should be provided with insulation, ventilation, and a sprinkling system. However, on some smaller ships insulation may not be available. Ships whose magazines are not exposed to abnormal temperature may not be provided with ventilation systems. Except in the case of small arms and fixed ammunition, smokeless powder charges in cartridges must NOT be stowed in the same magazine with projectiles or bag charges, nor should bag charges be stowed in the same magazine with fixed ammunition. Tanks for major caliber bag charges are stowed so that all covers are removable without disturbing the other tanks.

Semifixed cartridges must be stowed in separate magazines. If practicable, semifixed ammunition of different calibers should be stowed separately. When space limitations require, rocket motors may be stowed with semifixed cartridges. Fixed ammunition must be stowed in separate magazines.

Temperature Limitations

The most important factor in the stowage of smokeless powder is magazine temperature. The nature of decomposition of smokeless powder is discussed in detail later in this chapter. As you will learn, the most important causes of decomposition are high temperatures, excessive moisture, and the presence of acid. Experience has indicated that stowage in airtight containers at or about 70°F or less is entirely satisfactory for the normal life of any service powder. However, the stability of the powder diminishes rapidly as stowage temperatures rise and it is seriously threatened at above 100°F. Therefore, make every effort to maintain magazine temperatures below 100°F.

Exposure to abnormal temperatures for a limited time does not seriously affect the safety of the ammunition. Certain operating conditions frequently result in abnormal temperatures for short intervals in primary magazines, ready-service rooms, and deck lockers. Although the safety of the ammunition which has been subjected to abnormal temperatures may not be in jeopardy, its functioning may have been affected. For this reason, artificial cooling is advisable if temperatures exceed 100°F. Instructions in the following paragraphs may act as a guide for action when infrequent higher temperature conditions occur.

As stated in OP 4, the following action is required whenever smokeless powder has been exposed to the temperature ranges specified. Where artificial cooling is directed, the preceeding steps for artificial cooling should be followed. To summarize, the following actions are prescribed:

1. 90°F to 100°F.
   a. None.
2. 100°F to 110°F.
   a. Artificial cooling as practicable.
3. 110°F to 120°F.
   a. Artificial cooling as practicable.
   b. Segregate the ammunition and expend first during the next firing.
   c. Record the number of hours and the maximum temperature reached during each hour of exposure above 110°F. and less than 120°F.
   d. When the cumulative total of hours between 110°F and 120°F reaches 500 hours, the ammunition should be expended or turned in to an ammunition depot.
4. 120° to 130°F.
   a. Artificial cooling as practicable.
   b. Segregate the ammunition and expend first during next firing.
   c. Record the number of hours and the maximum temperature reached during each hour of exposure above 120°F and less than 130°F.
   d. When the cumulative total of 100 hours of exposure above 120°F is reached, and prior to a cumulative total of 500 hours of exposure between 110°F and 120°F, the ammunition should be expended or turned into an ammunition depot at the first opportunity.

5. Above 130°F.

At temperatures above 130°F, the ammunition should be expended or turned in to the nearest ammunition storage activity. If no storage activity is immediately available and the ship is in port, the powder may be retained on board in a segregated magazine or in a ready-service room or locker. However, all methods practicable shall be used to lower the temperature of this powder until the ship proceeds to a suitable area as defined in NAVORD Instruction 8026.9 for safe dumping overboard.

FIXED AMMUNITION

Fixed ammunition will be stowed in separate magazines where no other ammunition is stowed. The magazines for this ammunition must be equipped with approved racks, stanchions, and other devices to provide rigid and safe stowage for the ammunition. Temperature and sprinkling controls will also be provided.

Stowage by Type

Rockets, when shipped with head and motor in the same container but unfuzed and unassembled, may be stowed with fixed ammunition when stowage space is limited. Fixed ammunition should be segregated by size and type insofar as practicable. Fixed ammunition containing white phosphorus may be stowed with other ammunition containing WP regardless of type.

SMALL-ARMS AMMUNITION

Small-arms ammunition shall be stored in a separate magazine. If this is impractical and no other storage is specifically provided for the following materials, they may be stored in small-arms magazines:

(1) Service and drill lock primers and torpedo impulse primers.

(2) Torpedo igniters and torpedo super-heater fuzes.

(3) Ignition fuzes for landing force ammunition.

(4) Ballistite (or other powder) rings for mortar ammunition.

(5) Shotgun shells.

(6) Special small-arms blank cartridges.

(7) Hand grenades, loaded with E.C. powder only, with firing mechanisms assembled; all packed in hermetically sealed packing containers.

(8) Bomb ejector cartridges.

(9) Blank charges for caliber .45 line-throwing projectiles except when the caliber .45 line-throwing box and equipment is prepared for ready service.

Stowage of Primers

Primers shall be stowed in primer magazines or in small-arms magazines. Primer stowages should be separated as far as practicable to prevent loss of all of one type in case of combat damage or accident. On ships with large allowances of small-arms ammunition and where more than one magazine is designated for small-arms stowage, the stowage of lock primers should be distributed among the safest small-arms magazines to reduce the hazard of accidental loss or damage of all primers.

BLACK POWDER

Black powder in bulk preferably is stowed in a separate magazine. When necessary, the following materials may be stowed with it.

1. Black powder blank charges for saluting, signaling, or training
2. Black powder torpedo-impulse charges
3. Black powder line-throwing charges
4. Spare powder bags with attached black powder ignition pads if stowed in airtight powder tanks
5. Black powder depth charge impulse charges

Alternate Permissible Stowage

Should the ship you are doing duty on not have a designated black powder stowage space aboard, conveniently located 20-mm ready-service rooms or lockers equipped with sprinkling systems may be used. Suitable fittings for assembled saluting and impulse charges must be provided and all 20-mm ammunition must be removed.

SEPARATE LOADING PROJECTILES

Separate loading projectiles of different types of bursting charges shall be stowed in separate magazines, if possible. Magazines designated for storage of separate loading projectiles are equipped with designated fittings, metal bins, or racks to secure and protect the projectiles, bands, fuzes, caps, and wind-shields. Stowage for large caliber projectiles usually is base down with some security against tumbling or other movment. Normally medium caliber projectiles are stowed horizontally with grommets attached. Grommets shall remain in place for all horizontal stowage. Grommets are not to be removed from any projectile until projectiles are prepared for firing, except for main battery service projectiles which shall be stowed with grommets removed. Damaged grommets shall be repaired or replaced by the ship in case the projectiles are returned to a shore activity. Upon request, grommets for main battery service projectiles can be furnished to ships by the naval ammunition activity to which the projectiles are to be turned in; they shall be placed on the projectiles by ship's force prior to removal from their regular storage space.

Other Authorized Stowage

Where no other magazines are specifically provided, the following materials may be stowed in separate loading projectile magazines.

(1) Mortar projectiles loaded with high explosives and plugged and without assembled boosters, fuzes or detonators, propellant rings, or cartridges.

(2) Mortar practice projectiles without assembled boosters, fuzes, propellant rings, or cartridges.

(3) All separate loading illuminating projectiles.

(4) Rocket heads under 200 pounds gross weight.

(5) Dummy drill ammunition shall not be stored in magazines.

Separate loading projectiles of different types of bursting charges should be stowed in separate magazines if practicable; however, it is mandatory that projectiles and rocket heads containing WP be stowed separate from high explosive-loaded projectiles. They MUST be stowed in accordance with the instructions for chemical ammunition, covered later in this chapter.

BOMB-TYPE AMMUNITION

The ratio of explosive filler to total weight of a bomb may vary from as little as 10 percent to as much as 80 percent. Despite this large variation, bomb-type ammunition is regarded as thin-walled. It is vulnerable to damage by relatively slight contact with either sharp or blunt objects or hard surfaces. This type of ammunition is regarded as one of the most hazardous because of its tendency to detonate en masse if subjected to shock or involved in fire. Because of the container-dent sensitivity of bomb-type ammunition, it shall be handled and stored with care to prevent damage. Magazines for bomb-type ammunition shall be located behind armor plate or other suitable protection against high velocity fragments.

Magazines for Bomb-Type Ammunition

Bomb-type ammunition shall be stored in separate magazines in which no other ammunition is stored or in specially designated tubes, racks, tracks, or lockers. If possible, several magazines should be provided for the storage of warheads, aircraft bombs, depth charges, mines, demolition charges, and other kinds of bomb-type ammunition. When sufficient magazines are provided and when stowing arrangements and fittings permit, the following considerations will govern the stowage.

1. Not more than one kind of high explosive to be stowed in one magazine, for instance, bombs filled with composition B should not be stowed with bombs filled with HBX.

2. Different kinds of bomb type ammunition to be stowed separately, for instance, general-purpose bombs should be stowed separately from armor-piercing bombs.

3. When practicable, equal amounts of high explosives are to be stowed in each magazine. In other words, two magazines designated as general-purpose bomb magazines should receive equal amounts of general-purpose bombs.

4. The stowage arrangement should permit visual inspection.

5. The height of bearers of the lowest rows should be consistent with space required for cleaning.

6. Portable fittings are permitted in aisles and passageways if handling space is adequate.
7. No detonators, other initiating substances, or items containing initiating substances may be stowed in or taken into bomb type magazines.

In ships where space and weight considerations are critical or where loadings authorized for special missions exceed service allowances, bombs with different kinds of main high explosive charges may be stowed in the same magazine. Experience indicates that the quality of main high explosive charges currently used in bomb-type ammunition is such that there is practically no exudate. Stowage facilities which permit examination and cleaning of individual units of bomb-type ammunition are not required. Arrangements shall permit visual inspection.

WARHEADS

An explosive warhead must be handled carefully since it may detonate if subjected to intense shock. If handled roughly or dropped, it may be damaged so that it will not detonate properly in service use. The handling precautions prescribed for bomb-type ammunition also apply to warheads. Warheads shall be stowed in special warhead lockers or in bomb-type ammunition magazines. They shall be unpacked and their bases shall rest in stowage rings provided by NAVORDSYSCOM; they shall be firmly secured to prevent movement. Pit spaces and stowage racks must be equipped with a magazine-type sprinkler system. Boosters which do not contain detonators and which are integral parts of warheads or which are designed for stowage in warheads may be stowed in the warheads or in the warhead magazines. Warheads assembled with detonators or firing mechanisms containing a detonator shall not be stowed in a magazine unless authorized by NAVORDSYSCOM.

MINES, DEPTH CHARGES, AND DEMOLITION CHARGES

Mines, depth charges, and demolition charges MUST be stowed in bomb type magazines or in specially designed racks, tracks, or rooms. Detonators and firing devices containing detonators must NOT be stowed in, or taken into, bomb type magazines.

Mines, depth charges, and demolition charges assembled with detonators and carried in the ready condition must be stowed and guarded in accordance with the instructions prescribed for these materials. Before returning such materials to magazines, detonators must be removed and all components stowed in the proper magazine.

If you are striking for GM1 or GMC, you will be subject to examination questions on the types and characteristics of demolition explosives and safety precautions for their handling and stowage. NAVPERS 10185, GMG 3 & 2, covers the types and characteristics of demolition explosives, and will not be repeated here. However, following are some additional safety precautions for their handling and stowage.

1. Don't stow explosives in damp places.
2. When the explosives and demolition material are not in use, keep them locked up.
3. Keep blasting caps in their boxes, and keep the boxes covered. Never carry caps loose in your pockets.
4. Since blasting caps contain initiating compounds, they are extremely sensitive. They MUST be stowed in a separate place, well separated from all other explosives. Do not carry caps and explosives in the same vehicle unless it is absolutely necessary.
5. Detonating cord initiator contains initiating compound; handle it as carefully as you would a blasting cap.

DETONATORS, FUZES, AND BOOSTERS

DETONATORS for bomb type ammunition and other detonators requiring stowage separate from ammunition in which they are to be assembled MUST be stowed separately in detonator lockers. Such lockers will be located in approved places below the waterline or protective deck in large ships and above the weather deck in small craft. The locations are approved by NAVORDSYSCOM and are shown on the ship's plans. Not more than 100 detonators may be stowed in any one locker and no two lockers will be less than 10 feet apart. Individual detonators must be stowed in standard containers or in specially designed stowage blocks.

Detonators must NEVER be stowed in proximity to high explosive charges, or adjacent to bomb type magazines. They MUST be kept away from fires, steam piping, electric apparatus, and locations which are liable to heavy shocks. Electric detonators must not be located in the same compartment with, or within 5 feet of, radio apparatus or antenna leads.

FUZES AND BOOSTERS.—Which are not permitted to be stowed assembled in bomb type or other ammunition must be stowed in specially designed fuze magazines which must not be located adjacent to magazines containing high explosives. Ready-service fuze stowages are located at assembly points or near launchers and are shown on ship's plans. Mechanical time fuzes and point detonating fuzes for interchangeable assembly in separate loading projectiles may be stowed in specially designed lockers located within the projectile magazine, or close to projectile hoists within the gun installation. Electrically or radio-operated fuzes must NEVER be stowed in the same compartment with or within 5 feet of, radio apparatus or antenna leads.

GRENADES

Hand grenades loaded with Explosive Composition (E.C.) powder only and fuzed may be stowed in small-arms magazines. Fragmentation hand grenades which are high explosive loaded, plugged, and have the fuzes removed may be stowed in separate loading projectiles or fixed ammunition magazines. Offensive hand and rifle grenades which are high explosive loaded but without fuzes may be stowed in bomb-type magazines. On ships where there are no bomb-type magazines, these grenades may be stowed in a grenade body locker. WP smoke hand and rifle grenades which are plugged and have the fuzes removed may be stowed like chemical ammunition, separate from other types. Hand and rifle grenades, lachyrymatory (CN), plugged, and with fuzes removed may be stowed in chemical ammunition magazines. Dummy rifle or hand grenades (dummy drill ammunition) shall not be stowed in a magazine.

IGNITERS

Torpedo igniters and JATO igniters may be stowed in a fuze locker or magazine. The igniters must not be stowed in the same compartment with, or within 5 feet of, radio apparatus or antenna leads.

Detonators which are not assembled and sealed within a fuze as an integral part of it—that is, detonators requiring separate stowage—must not be stored in a fuze magazine that contains explosive-loaded fuzes, explosive boosters, or explosives of any kind other than detonators.

Auxiliary boosters and boosters which do not have a detonator assembled with them may be stowed with the bomb type ammunition to which they belong.

Boosters which are an integral part of bomb type ammunition and which are designed for stowage with bomb type ammunition need not be removed from that ammunition for separate stowage in fuze magazines.

Protection from Damage

Except when required for ready-service stowage or when assembled in ready-service ammunition, fuzes and boosters should be kept stowed in their individual containers, usually hermetically sealed cans, or in their shipping containers.

PYROTECHNIC AMMUNITION STOWAGE AT SEA

Pyrotechnics and pyrotechnic ammunition MUST be stowed separately in cool, dry magazines below decks, preferably above the waterline, or in special pyrotechnic lockers located on the weather decks. If large quantities of pyrotechnics are on hand, they should be segregated by type. Signaling pyrotechnics for boats must be packed in watertight boxes and stowed within the boat. Submarines will stow pyrotechnics in approved, designated spaces which are indicated on the ship's plans.

Pyrotechnics must be stowed in the individual containers and shipping boxes in which received. The stowage spaces should be dry at all times since moisture causes rapid deterioration and since some pyrotechnics are water activated. The temperature should be maintained below 100°F to prevent deterioration of the pyrotechnic mixtures or compounds.

Pyrotechnic Stowage In Port

Ships arriving in port shall remove all pyrotechnic items stowed in racks, life rafts, or other open locations and restow them in pyrotechnic lockers or ready-service magazines which shall then be locked.

CHEMICAL AMMUNITION

As a rule, chemical ammunition must be stowed in dry, well-ventilated enclosures on the upper decks, convenient for jettisoning in an emergency. The different types of chemical ammunition should, if practicable, be stowed separately. For some items, separate stowage is mandatory. If the quantity of chemical ammunition is large, separate stowage by type is mandatory and, in most instances, individual instructions for stowage will be issued by NAVORDSYSCOM. In cases where toxic gas ammunition is to be stowed afloat, NAVORDSYSCOM will supply specially trained personnel to handle and stow the ammunition.

Smoke

Containers of FM (TITANIUM TETRACHLORIDE) and FS (SULFUR TIOXIDE PLUS CHLOROSULFONIC ACID) smoke mixtures must be stowed on the weather decks, well aft, in a position convenient for supplying planes or smoke generators. They must be protected from exposure to weather or direct rays of the sun by suitable covering, and must be stowed away from ventilation intakes or other openings which might allow smoke to be sucked into the ship.

HC (HEXACHLORETHANE - TYPE MIXTURES) smoke mixtures must be stowed separately in topside stowages convenient for jettisoning. The stowage should be dry and away from ventilation intakes or other openings which might allow smoke to be sucked into the ship.

WP (WHITE PHOSPHORUS) loaded munitions require separate stowage. This stowage should be topside, convenient for jettisoning, and not located near ventilarion intakes. Such locations should be protected from direct sunlight, rain, spray, or other conditions causing corrosion to containers. In addition, WP munitions must be stowed in a space where temperatures can be controlled below 100°F since WP melts at 110°F. Sprinkling systems must be provided for all stowages of WP munitions. If reasons of temperature control demand, WP may be stowed separately below decks in a space which can be rapidly and completely flooded. If ventilating systems are present in this space, they should not be capable of recirculating the acrid WP smoke throughout the ship. All WP projectiles and rocket heads must be stowed base down to keep them from becoming unbalanced should the WP melt and subsequently solidify.

Loaded WP ammunition should not be subject to rough handling lest the airtight integrity of the ammunition be destroyed. Since WP is a moderate incendiary agent, in the event of a fire the ammunition should be promptly flooded with water to extinguish the blaze and cool the containers. Involved personnel should wear safety goggles or suitable face shields and rubber gloves, and should keep both their gloves and shoes (preferably rubber boots) wet. Vapors of WP are poisonous; however, no vapors are found in the acrid smoke. WP fires can be controlled by the application of low velocity water-spray. However, WP will re-ignite when the water has dried from it. Exposed WP shall be kept wet until all traces are washed or scraped overboard. Fires involving small quantities of WP can be extinguished permanently with repeated applications of 5 percent copper sulphate solution which reacts with the WP to form an inert coating.

Incendiary Munitions

Incendiary munitions require separate stowage; when they are carried in large quantities, individual stowage instructions will be issued by NAVORDSYSCOM. Small quantities may be stowed topside, convenient for jettisoning as in the case of WP. The space should be as remote from other munitions as possible. If stowed below decks, the space must be fitted with sprinkling systems capable of rapid and complete flooding of the compartment. Small amounts of incendiaries may be stowed with WP; however, sodium-filled igniters may not be stowed with any other munition. Sodium fires must not be fought with water; therefore stowage spaces for sodium igniters must not be equipped with sprinkling systems.

ARTILLERY AND LANDING FORCE AMMUNITION

It is desirable to stow the various types and components of artillery and landing force ammunition in separate magazines. When this is impracticable, the following stowage is permissible.

1. Mortar projectiles, plugged, with fuzes, boosters, and propellants removed as follows:
   a. High explosive projectiles in separate loading projectile magazines
   b. Practice projectiles in separate loading projectile magazines
   c. Smoke projectiles in chemical magazines
2. Booster and detonating fuzes for mortar projectiles in fuze magazines

3. Ignition fuzes for mortar projectiles in small arms ammunition magazines

4. Propellant rings for mortar ammunition in smokeless-powder magazines and ignition cartridges for mortar ammunition in small arms magazines

5. Hand grenades, loaded with E.C. powder and fuzed, in small arms magazines

6. Hand grenades, fragmentation, high explosive-loaded, plugged, with fuzes removed, in separate loading projectile or fixed ammunition magazines

7. Hand grenades and rifle grenades, offensive, high explosive-loaded, without fuzes, in bomb type magazines

8. Hand and rifle grenades, smoke (WP), plugged, with fuzes removed, as for chemical ammunition, separate from other types

9. Hand and rifle grenades, lachrymatory (CN—CHLORACETOPHENONE), plugged, with fuzes removed, in chemical ammunition magazines

10. Detonating firing mechanisms and detonating fuzes for hand and rifle grenades in fuze magazines, preferably on the weather deck in a cool, dry place.

11. Propellant special .30 caliber blank cartridges for rifle grenades in small arms magazines

12. 3''.5 (bazooka) rockets. The various types of 3''.5 rockets may be stowed in their shipping containers as follows:

   a. HE-loaded rockets must be given separate stowage as in the case of bomb type ammunition
   b. 3''.5 rockets with smoke-filled heads must be stowed as chemical ammunition
   c. 3''.5 practice rockets (inert heads) may be stowed with fixed ammunition, with rocket motors, or with smokeless powder

Demolition Equipment

Ships which have an allowance of one or more demolition kits normally have a space designated for stowage of the demolition blocks provided. The detonators for this equipment will be stowed in accordance with previous instructions and the inert accessories may be stowed in any convenient location.

ROCKET TYPE AMMUNITION

Aircraft Rockets

Aircraft rocket motors currently are being issued in wooden shipping containers or in combination launcher-shipper containers with and without the rocket heads. They must be stowed in these containers aboard aircraft carriers.

AUTHORIZED UNBOXED STOWAGE.—Twenty percent of the 3''.25 and 5''.0 rocket motors stowed aboard aircraft carriers may be stowed unboxed with fin assemblies attached. When stowed unboxed, the following requirements must be incorporated in the stowage arrangements.

1. They must be supported at two points and the spacing between supports will be 15 inches or greater, with supports located approximately equal distances from the center of the rocket motor. The supports must not interfere with launching lug bands and must adequately protect the motor against any motion or shifting. Stacking in any manner wherein the motors would rest upon each other is prohibited, and stowage must be in a horizontal position.

2. The electric system must be adequately protected so that no breaks or short circuits will result from the unboxed stowage. All external fittings must be protected against damage or deformation of the metal parts so as to avoid damage to, or dislocation of, the propellant grain.

TYPES OF MAGAZINES. — Rocket motors should be stowed in primary magazines; they may be stowed with semifixed cartridges when space limitations require. Small numbers of rocket motors, except those normally furnished assembled, may be stowed in ready-service magazines, compartments, or lockers. Rockets received in launcher-shipper packages should be stowed separately in fixed ammunition magazines. They may be stowed with fixed ammunition when space limitations require. Rocket igniter squibs are initiated electrically; therefore, rocket motors must not be located in the same compartment with, or within 5 feet of, radio apparatus or antenna leads. Igniter lead jack plugs or other electrical connectors must have shorting clips attached at all times of otherwise short-circuited except when the connector is being inserted into the electrical receptacle at the aircraft.

Stowage for crated FIN ASSEMBLIES may be provided in ordnance storerooms or in any other accessible space not fitted out as a magazine. Uncrated stowage of the fin assemblies in the vicinity of the rocket assembly area is authorized provided fin assemblies are secured in place to prevent damage.

ROCKET HEADS must be stowed uncrated in primary bomb or projectile type magazines. Heads, each less than 200 pounds in gross weight, are stowed as separate loading projectiles; those more than 200 pounds in gross weight are stowed in bomb type magazines. Chemical-filled heads are stowed as chemical ammunition. The stowage regulations for heads are the same as those specified earlier for separate loading projectiles and bomb type ammunition. Stowage for solid rocket heads are the same as for inert ammunition.

NOSE FUZES for surface-launched rockets shall be stowed in their individual sealed containers. Stowage regulations are the same as those specified for other fuzes and boosters.

ASSEMBLED ROCKETS.—Ready-service stowage for assembled aircraft rockets other than those received assembled is not authorized. A separate locker may be provided for stowing ready-service nose fuzes at a point close to the assembly area.

Aircraft rockets, when shipped with head and motor in the same container, assembled or unassembled, must be stowed in their shipping containers in fixed ammunition type magazines.

Surface-Launched Rockets

Stowage of surface-launched rockets aboard beach barrage and antisubmarine warfare type vessels must be separate and unassembled in the shipping containers with the following exceptions.

Commanding officers may authorize ready-service stowage of assembled but unfuzed rockets in the original shipping containers when such containers are designed for or permit such stowage.

During conditions of wartime readiness, the officer in tactical command may authorize any quantity of rockets required to be completely assembled and fuzed. Complete rounds must be pointed outboard when topside and must be in outboard compartments when below decks. This authority must not be interpreted as blanket authority for continuous ready-service stowage in noncombat areas or when the situation does not demand such measures. Most rocket motors are nonpropulsive when the heads are not assembled on the motors. In case of fire or conflagration, the unassembled motors will burn at both ends and equal thrust will be developed on each end. The intense pressure required for the rapid burning of rocket propellants will not develop in unassembled rocket motors and the burning will be relatively slow. For these reasons, stowage of assembled rockets is permitted only when the exigencies of the situation outweigh the risks involved. The stowage of fuzed rocket ammunition in the launcher is not permitted in friendly anchorages or within striking range of friendly shores.

Spin-stabilized rockets stowed assembled in designated containers, though propulsive, will not arm if ignited, nor is it probable that the head will detonate from the heat of its own burning motor. For this reason, the stowage of assembled, unfuzed spin-stabilized rockets, though less desirable than unassembled stowage, is an acceptable risk during wartime.

NOSE FUZES for surface-launched rockets must be removed from their wooden shipping containers and stowed in their individual sealed containers. The stowage is the same as previously specified for fuzes. Ready-service stowage of fuzes in a cool, dry place close to the launcher or assembly area is permissible.

Temperature Control

All data available indicates that new rocket propellant which has not been exposed to abnormal temperatures is as safe as new single-base smokeless powder. Since no shipboard surveillance tests by which to evaluate stowage conditions have been approved for rocket propellants, rocket ammunition should always be stowed so that the oldest lots will be fired first. The age of a lot is determined by the last assembly date and not by the length of time it has been aboard.

TEMPERATURE LIMITATIONS.—The temperature limitations and temperature control regulations for magazines containing rocket motors are the same as those for magazines containing smokeless powder.

Whenever rocket motors have been exposed to temperatures ranging between 110°F and

120°F for 500 hours, they shall be expended, or segregated, suitably marked, and turned in to the nearest ammunition activity at the first opportunity. A log will be kept of magazine temperatures in excess of 100°F in the same manner as that prescribed for smokeless powder.

Whenever rocket motors have been exposed to temperatures ranging between 120°F and 130°F for any period of time, they must be segregated, suitably marked, and turned into an ammunition activity at the first opportunity.

Whenever rocket motors have been exposed to temperatures in excess of 130°F, they shall be expended or turned into an ammunition depot at the first opportunity.

JET ASSISTED TAKEOFF (JATO) UNITS

JATO units may be stowed with rocket motor types of ammunition in magazines fitted with temperature controls and sprinkling systems. Flammable dunnage other than pallets on which shipped shall not be used in JATO magazines.

Temperature Control

Strict control of temperature must be maintained in JATO magazines to prevent slumping or cracking of the propellant when subjected to extremes of temperature. Each magazine must be equipped with two maximum and minimum thermometers and the thermometers are to be located in the warmest and the coolest parts of the magazine.

All JATO units have their upper and lower temperature limits stenciled on their side. The units may be stowed or fired outside of these limits ONLY if the following two conditions are met.

1. The units have not been subjected to temperatures outside the range of +145°F to -40°F.

2. The total cumulative time of exposure to the ranges of 130°F to 145°F and 0°F to -40°F does not exceed one hour.

Should units be exposed to the conditions of either steps above, they must be clearly marked UNSAFE for use. NAVAIRSYSCOM will be informed of all the attendant circumstances when JATO units are declared unsafe for use in order that disposition may be made.

JATO Igniters

JATO igniters must be stowed separate from JATO units, preferably in a fuze locker or magazine. The igniters must not be stowed in the same compartment with, or within 5 feet of radio apparatus or antenna leads.

MISCELLANEOUS AMMUNITION

Torpedo torch pots must be stowed in watertight lockers on weather decks of surface vessels. No sprinkling system is permitted in this stowage and under no circumstances will stowage be below decks. Torpedo torch pots may never be stowed permanently aboard a submarine, nor may they be used on torpedoes which are fired when the submarine is submerged.

Blank charges for caliber .45 line-throwing guns will be stowed in small-arms ammunition magazines.

Experimental explosives or ammunition must be stowed separate from all other explosives.

Dummy drill ammunition must not be stowed in magazines with live-loaded ammunition.

Inert ammunition components, not a part of an assembly or subassembly of an item of explosives, except powder and cartridge tanks and boxes, cartridge cases with fired primers, line-throwing projectiles, lines and spindles, and inert firing devices for mines and depth charges, must not be stored in magazines with explosives.

On completion of firing, empty powder and cartridge tanks and boxes may be allowed to remain in the magazine where they were stored prior to the firing until the first opportunity for transferring them to an ammunition activity, provided that access to tanks containing service or target powder is not thereby impeded. Such tanks must be marked "EMPTY."

Fired cartridge cases must be placed on their bases in the open air for at least 10 minutes then thoroughly brushed to remove residue. They may then be returned to their containers which must be marked or tagged "EMPTY CARTRIDGE CASE" then stored in the magazine in which formerly stowed. Permanent containers, spacers, fuze covers, and other permanent inert shipping accessories should be returned to the nearest ammunition activity as soon as practicable after expenditure of the ammunition.

Privately owned ammunition will be stored as appropriate for the particular type of ammunition.

OP 4 states that should the exigencies of war require mixed stowage of ammunition, such ammunition will be segregated insofar as practicable according to the hazard classification. The hazard classification for all ammunition is tabulated in OP 5, Vol 2, 3rd Rev.

When special or unusual stowage of large quantities of ammunition, or when stowage of special ammunition becomes necessary, NAVORD will issue special directives and render technical assistance, as required, for the stowage.

CHART OF PERMISSIBLE STOWAGES

As you know, original ship's plans provide magazines for each type of ammunition required to be stored and these plans must normally be followed. However, original ammunition stowage requirements may be modified which, in turn, may require mixed stowages of ammunition in the same magazine. In these cases the Chart of Permissible Stowages, OP 4, Volume 2 must be used in determining the proper stowage combination.

Stowage of Equipment in Magazines

Normally the stowage of any articles other than ammunition or explosives in spaces designated as magazines is forbidden. This remains in effect even though the magazines are not required for stowage of ammunition. An exception to this regulation has been made for small ships to permit supplies and equipage to be stowed in magazines if the sprinkling system is blanked off but tested as usual; the space can be rendered usable as a magazine within 24 hours; ammunition is not consolidated in fewer magazines to make space available for equipage stowage; and no flammable material is stowed in these spaces.

SURFACE LAUNCHED MISSILES

Surface launched missiles are ready service complete rounds of ammunition. They are stored in specially designed magazines and or launcher cells. The complete missile is a mixture of mechanical, electrical, electronic equipments and several different explosives components. Regardless of where the missiles are stored, the same safety precautions for explosive hazards in magazine areas must be observed in all types of missile storage areas.

The types of surface launched missiles handled by personnel in the GMG ratings are ASROC, SPARROW AND ZUNI missiles. The ASROC missile is used as an ASW weapon and is stored in either a magazine or launcher cell in a ready service condition. The SPARROW missile is used with the Basic Point Defense Surface Missile System (BPDSMS) and is stored in a ready service condition in an eight cell launcher. The ZUNI rocket is used with the CHAFFROC DECOY SYSTEM and is stored in a ready service condition in a four tube launcher pod. ZUNI components also are stored in ready service lockers.

ASROC and Torpedo Magazines

The ASROC missile magazine provides stowage for additional ASROC missiles. The magazine contains stowage racks especially constructed for spare components, hand lift trucks, one missile container, and necessary hardware for handling. The magazine is located near the launcher and on the same level for easy transfer of the missile to the position required for loading or unloading launcher cells. The magazine is fully enclosed, and has access doors that conform to the safety and security requirements, for stowing ASROC missiles. Specially constructed blowout patches also are provided. A sprinkler system is installed in the ASROC magazine for fire protection.

Stowage racks for missiles are constructed of removable hardware mounted in a restraining frame assembly with necessary hardware to clamp the missile in position. Stowage racks are provided in or near the magazine to hold spare components of the missile. Shelves of the stowage racks are designed to dimensions that accomodate missile spare components. Some components may be stowed unpacked. Spare nose caps for both depth charge and torpedoes, missile cable assemblies, flexible breech covers, and an air sampler fit compactly into stowage racks. The air sampler may be stowed outside the magazine.

HANDLING TECHNIQUES

This section on handling techniques will point out some of the more important regulations, safety orders, and precautions to be observed in handling ammunition, as well as the handling equipment and methods that may be used when regular handling gear is not available.

The utmost care and prudence must be exercised in handling and transporting all kinds of ammunition and explosives by all officers and petty officers whose duties require cognizance over or actual handling of ammunition. Personnel in ammunition working parties are likely to become careless and indifferent when continually engaged in work with explosives and, as long as nothing occurs, are inclined to drift gradually into neglect of necessary safety precautions. Nothing but constant vigilance on the part of all officers and petty officers in charge will ensure steadfast observance of the rules and regulations which experience has taught to be necessary.

Safety precautions, rules, and regulations for handling explosives should be made the subject of frequent instructions, and the necessity for strict compliance with these procedures should be so firmly emphasized to new personnel that they will invariably and subconsciously observe all safety precautions, rules and regulations. Attention is especially invited to the fact that in the early stages of handling ammunition and explosives, experience was gained at a great price. There were several serious explosions in the early 1940's which were examples of what can happen when explosives are accidently detonated. Unfortunately there were, in most cases, no witnesses surviving these to testify as to what actually happened to cause them. Ordnance Safety Precautions, Their Origin and Necessity, OP 1014, presents case histories of actual casualties that have occured while handling and using ammunition and explosives. The purpose of OP 1014 is to impress naval personnel at all levels with the need for rigid adherence to all safety precautions, and the grave consequences of their violations.

MINIMUM HANDLING

The number of men allowed in the vicinity of explosives should, as far as practicable, depending upon the requirements of the operation, be reduced to the minimum for properly performing the work in hand. It frequently happens that unnecessarily large working parties are assembled for handling live ammunition. Every effort and known precaution is taken to make ammunition safe for handling under all conditions. This rule must be strictly followed to restrict as much as possible the danger and extent of injury to personnel in case of accident. Remember, handling ammunition should always be reduced to the minimum to reduce the chances of accidents.

EMBARKING AND DISCHARGING AMMUNITION

Since the paramount consideration is safety, ammunition and explosive's containers shall not be tumbled, dragged, thrown, or dropped on each other, or on deck.

PROJECTILES

Projectiles should not be rolled but should be handled by hand trucks, (for heavy projectiles) or by projectile carriers and slings. A loaded and fuzed projectile which has been dropped from a height exceeding 5 feet must be set aside and turned into an ammunition depot. Such projectiles should be clearly marked to show their condition and must be handled with the greatest care. Fuzes are so designed and manufactured that a fuzed projectile may be dropped without causing a fuze to function, but additional drops or the shock of firing may cause a fuze action. Rotating bands on projectiles for separate or semi-fixed ammunition have copper lips which are easily damaged. Particular care is required to prevent damage to the band. Extreme care should be taken in handling projectiles fitted with caps and or windshields to prevent loosening the cap or windshield. The caps and windshields should be protected from jolts and stress when being handled manually or with handling equipment. Slings should not be used which support a part of the weight of the projectile on the cap or windshield.

When projectiles must be rolled because it is the only handling means available, they shall be rolled carefully and slowly and prevented from bumping one another to protect the projectile bodies from damage and defacement and to guard against arming the fuze assembled in the projectile. They shall be kept under hand control at all times so as not to cause damage or loosening of windshields, caps, tracers, fuzes, bourrelets, rotating bands, and identification markings. Bale hooks and similar devices shall never be used on ammunition or ammunition containers. Projectiles shall not be rolled on steel decks but may be rolled over boards not less than 1-inch thick or other approved dunnage.

Special Purpose Projectiles

Rocket Assisted Projectile (RAP) shall be handled and stored under the same requirements as standard projectiles. The projectile shall be handled carefully at all times to avoid jarring or dropping. If, during the handling of a RAP projectile, a drop in excess of 24 inches should occur, the projectile shall be considered defective and turned over to authorized ordnance disposal personnel for disposition, except when a RAP projectile is dropped on its base.

Warning: During handling of RAP, a drop in excess of 24 inches on the base of the projectile in which a deck pin (rivethead) bolt, or miscellaneous object strikes the center hole of the igniter, sufficient striking energy could be provided to actuate the igniter. In this event, ignition of the rocket motor may be delayed 20 to 30 seconds. All personnel should immediately evacuate the area. Do not attempt disposal prior to rocket ignition. After a delay of at least one minute following rocket motor burn out, the projectile should be disposed of immediately by dumping.

Projectiles dropped less than 24 inches should be examined carefully for external damage. If no damage is evident, the projectile may be considered safe for use.

FIXED AMMUNITION

Each round of ammunition is carefully gaged prior to assembly and issue to make sure it fits into the gun for which it is designed. This ammunition is particularly subject to misalignment of projectile and cartridge case or to other deformations which may cause jams in loading unless it is handled very carefully at all times. When consideration is given to the design of fixed ammunition and to the relatively snug fit required in the gun for proper functioning, it is apparent that rough handling is certain to result in frequent interruptions in the rate of fire of the gun. When handling and storing fixed ammunition, the following precautions shall be observed.

Fixed ammunition shall never be dropped, rolled, or thrown. Boxes or tanks of fixed ammunition may be handled with roller conveyors, chutes, and hand trucks as long as precautions are taken to protect them against shock or damage.

Whenever a round of fixed ammunition is dropped a distance of 5 feet or more (including tanked or boxed rounds), the round shall be set aside, carefully marked, and turned into an ammunition activity at the first opportunity or dumped in deep water at the discretion of the commanding officer.

POWDER TANKS AND CARTRIDGE TANKS

Powder tanks containing bag charges shall not be rolled or dropped. Necessary handling operations shall be performed by carrying the filled tanks by hand or hand truck, being careful to prevent internal movement and possible ignition of the charge within the tank by static electricity.

When lifting and moving such tanked charges, the bottom of the tank shall be held lower than the top at all times.

Tanks containing separate loaded propelling charges should be handled carefully to prevent misalignment, damage to the round, or destruction of close tolerance dimensions. They may be handled with roller conveyors, chutes, or trucks as long as precautions against shocks are observed.

Tanks containing ammunition or explosives received or found damaged, or dropped in handling, shall be turned into an ammunition depot. Powder tanks are so constructed that they will remain airtight only as long as the gaskets to their removable covers remain in place. Covers must be secured with sealing wire.

When handling a fixed cartridge or a separate loaded cartridge out of their tanks, care shall be taken to protect the cartridge primer and projectile fuze.

RETURN OF SHIP'S AMMUNITION TO AMMUNITION ACTIVITIES

In spite of all surveillance and protective measures taken to preserve ammunition afloat, certain integral components of all ammunition are subject to deterioration and must be replaced or renewed through breakdown and renovation. Since the facilities and specially trained personnel required for such operations are not provided to forces afloat, these operations are authorized only at shore-based ammunition activities, and certain mobile ammunition renovations and evaluation units under the cognizance of NAVORDSYSCOM.

In most instances, small but essential components such as base fuzes, time fuzes, and auxiliary detonating fuzes are the only items requiring replacement. Through experience and quality evaluation, NAVORDSYSCOM has set definite age limits on most types of ammunition. Ammunition issued to forces afloat will have an expected serviceable life sufficient to encompass any normal stowage period afloat. It is the responsibility of the ammunition activity to ensure that only serviceable ammunition is issued to forces afloat or reissued whenever ammunition is put ashore during routine yard overhauls.

NORMAL RETURN OF AMMUNITION

During regularly scheduled major overhaul of ships, it is considered necessary and is required that all ammunition be removed from the ship in order to permit complete freedom of action on the part of shipyard overhaul personnel. Fleet return ammunition will be considered unserviceable until the proper inspection and renovation, if required, may be affected. Upon completion of yard availability, issues will be made to the ship from the ammunition activity's ready-service stock.

Procedure for Returning Ammunition

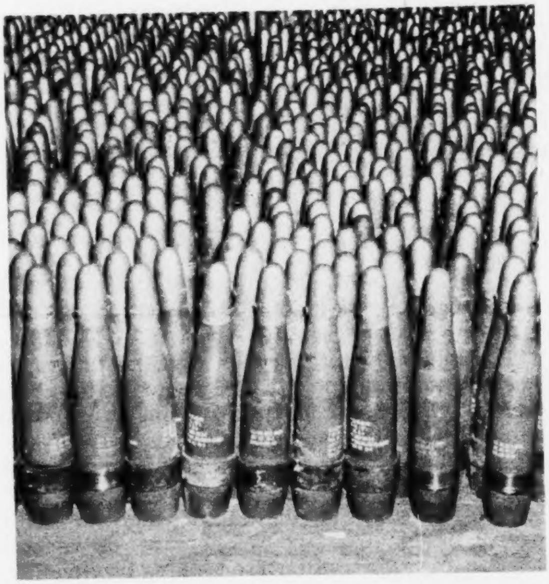
Prior to off-loading ammunition, the ship concerned should procure and follow the SOPA instructions, pertaining to the off-loading operations for that particular area. Also, contact with the activity concerned, usually base ordnance, should be made for confirmation of the SOPA instructions, thereby, making any changes that may be applicable to the existing instructions. Arrangements may also be made for a conference at which time all details of the off-loading procedure may be ironed out. This would include such items as time and place of off-loading, types and amounts of ammunition on board, number of lighters or barges needed, and types and amount of handling equipment required for the off-loading operation, (skip boxes, safety slings, lifting jacks, etc.).

The ammunition to be turned in must be segregated by types and, where practicable, by lots. All identification markings must be legible, or the ammunition tagged with complete identifying information. Ammunition known to be unserviceable, suspected ammunition, ammunition in partially filled containers and ammunition which has been in ready-service stowage, must be conspicuously marked or tagged to identify its contents.

All ammunition must be packages and protected in accordance with existing instructions. All grommets must be intact. Figure 11-1 illustrates projectiles improperly protected, missing grommets, figure 11-2 illustrates proper stowage. In all cases, ammunition which has been removed from containers for clipping or for design stowage must be placed in its original container or in a proper container whose markings agree with the ammunition inside. In cases where this cannot be accomplished, the ship will be held strictly responsible that the ammunition is segregated, securely packed for safe handling and transportation, and conspicuously tagged to indicate this condition.

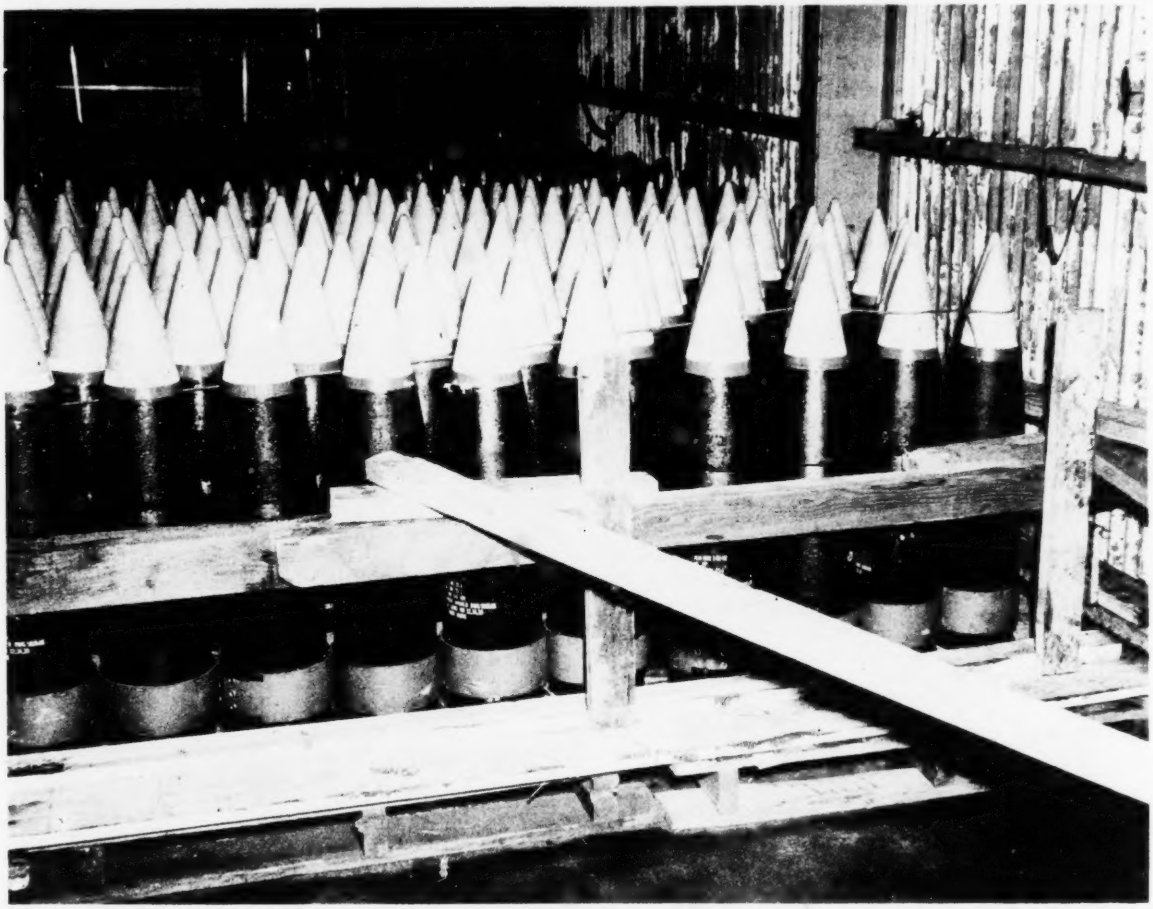
A complete inventory of the ammunition to be off-loaded must be furnished to the ammunition activity. Now, after your ship is in the assigned berth for loading or off-loading the ammunition, here are some things you can expect from the ammunition activity:

1. Each concerned ammunition activity will ensure that assistance is rendered to each ship



53.136

Figure 11-1.—Improper stowage—projectiles on steel deck, missing grommets.



53.137
Figure 11-2.—Proper stowage and bracing.

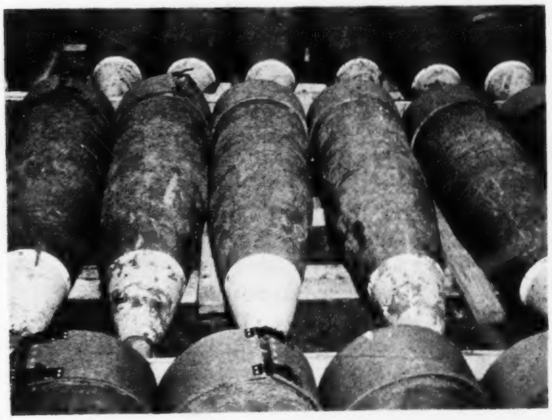
on loading or off-loading ammunition at that activity.

2. A qualified military or civilian employee of the ammunition activity will report to the commanding officer of the ship being worked to advise on the applicable explosives safety precautions, handling, and stowage of ammunition in lighters to ensure:

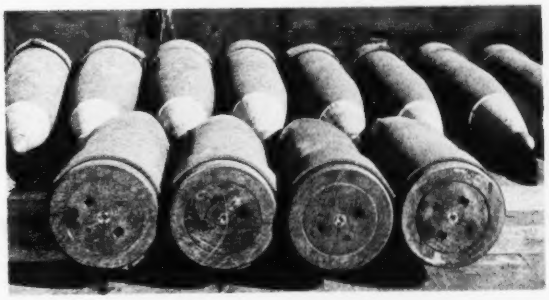
a. Delivery of the ammunition to ships on-loading and acceptance of receipt for ammunition from ships off-loading.
b. Safe and efficient handling of the ammunition either to or from the ship.
c. Efficient and safe stowage, blocking, and bracing of ammunition in the lighter.
d. Segregation of the ammunition, to the extent practicable, as it is off-loaded into the lighters, to effect efficient unloading at the ammunition activity.
e. That safety precautions for embarking and discharging ammunition are complied with.
f. Provision of any necessary equipment, such as slings, and carriers, for the safe and efficient handling of the ammunition to and from the ship.
g. Presence of qualified personnel and material necessary for effective dunnaging, blocking, and bracing of ammunition in lighters.

Even though the ammunition activities representative will be available for the supervision of arranging the ammunition on the lighter, you can be more rapidly prepared for the loading and off-loading operation if you are aware of the following requirements:

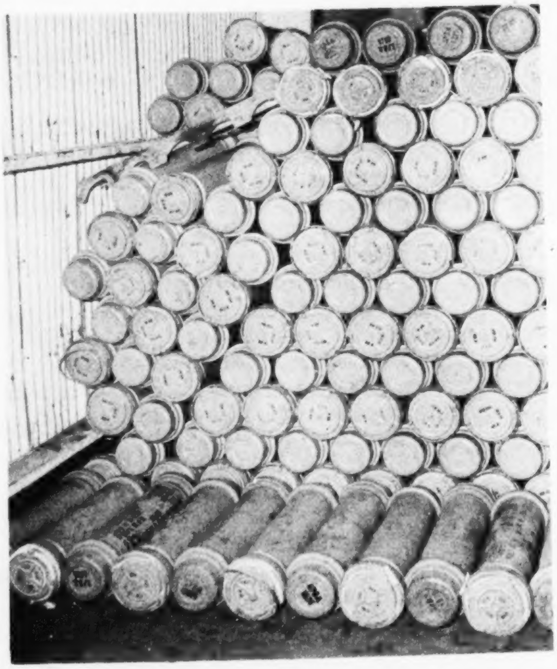
1. Heavy ammunition should be loaded "athwartship" in the center of the barge or lighter.
2. All projectiles stowed on their bases require solid decking.
3. Runners only are required for all other projectiles, cartridge cases, and powder tanks.
4. All projectiles stowed on their sides must be stowed "nose to nose" and "base to base" (figs. 11-3 and 11-4).
5. All ammunition is to be properly shored, (figs. 11-5 and 11-6).



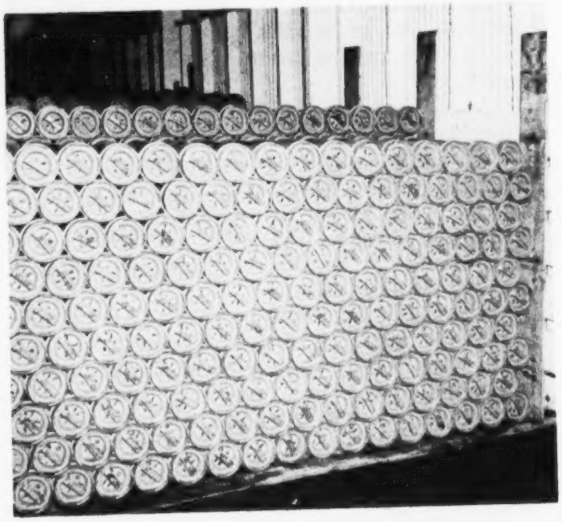
53.140
Figure 11-3.—Improper stowage—projectiles nose to base.



53.141
Figure 11-4.—Proper stowage of projectiles "nose to nose", "base to base."



53.142
Figure 11-5.—Improper stowage—no dunnage.



53.143
Figure 11-6.—Proper stowage and dunnage.

Applicable Publications

OP 2140, Ammunition Palletizing and Carloading, describes and illustrates procedures for palletizing and carloading ammunition in freight cars.

OP 2165, Navy Transportation Safety Handbook, describes existing regulations pertaining to the safe handling and transportation of ammunition, explosives, and other dangerous articles.

OP 2173, Catalog of Handling Equipment for Weapons And Explosives, lists authorized handling equipment used afloat and ashore for conventional weapons, ammunition and explosives as well as guided missiles. It also lists the safety precautions and instructions pertaining to the safe operation and use of handling equipment.

HANDLING EQUIPMENT

The task of ammunition and explosive handling is enormous and, by nature, inescapably hazardous. Accidents arising in ammunition and explosives handling kill, injure, and destroy essential equipment.

These accidents do not "just happen." They are caused by carelessness or unfamiliarity with the use and limitations of handling equipment as well as relaxation or failure in observance of safety precautions, orders, and regulations pertaining to handling ammunition and explosives.

When ammunition is being embarked from a ship at sea or inport, all safety precautions, orders, and instructions shall be strictly observed.

Cargo Nets

When ammunition is being embarked or discharged from a ship in port, a cargo net should be rigged between the ship and dock or ship and ammunition lighter to catch any ammunition that may be dropped.

Cargo nets shall not be used for transferring explosives and ammunition except to enclose a pallet, skip board, or tray. In hoisting or lowering containers with cargo nets, a rigid wooden platform shall be fitted in the net upon which the container can be placed.

Pie Plate

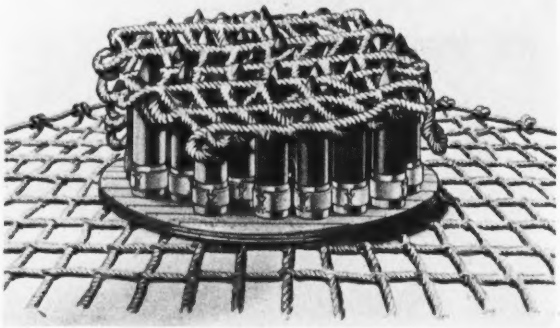
The pie plate is a circular wooden platform of three-ply material. A pie plate may vary somewhat in size but it should be strong enough to bear the load with a good margin of safety, and should be sufficiently rigid so that it will not bend.

The pie plate generally is used to transport loose ammunition. The pie plate is used with a second cargo net to prevent the shifting and bumping of the load, and it also prevents crushing the load when the net is lifted. Figure 11-7 illustrates the pie plate with a cargo net. When a second net is used with projectiles, it should be pushed down to force the points of the projectiles up through the net. The pie plate is used aboard ship when returning unserviceable ammunition to an ammunition ship at sea.

Ammunition Slides and Chutes

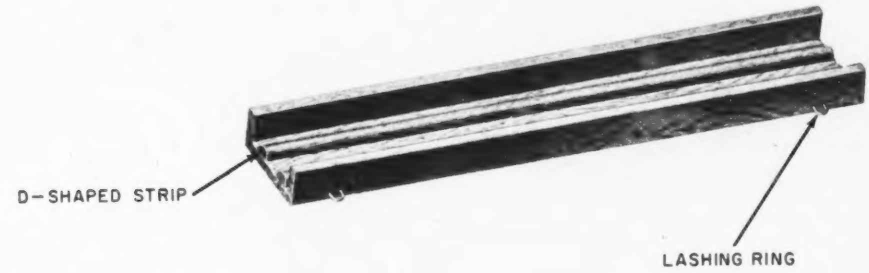
The ammunition slide, figure 11-8, is constructed of smooth-planed boards not less than 1 inch thick with sides of the same material 4 inches high. The assembly is made with brass screws only. D-shaped wooden strips run lengthwise on the inner face of the chute. They are fastened to the upper surface of the slide by glue and wooden bowels extended through the bottom of the chute. No metallic fasteners used in construction protrude above or beyond the inner face of the chute. A lashing ring at each corner of the chute secures it during use.

The ammunition slide is used to move projectiles and powder tanks to a lower level. Cargo mats or other forms of dunnage are used



5.61.3

Figure 11-7. —Pie plate placed on a cargo net and loaded with projectiles.



53.312
Figure 11-8.—Slide, ammunition.

at the bottom of the slide. The ammunition slide is also used at shore stations.

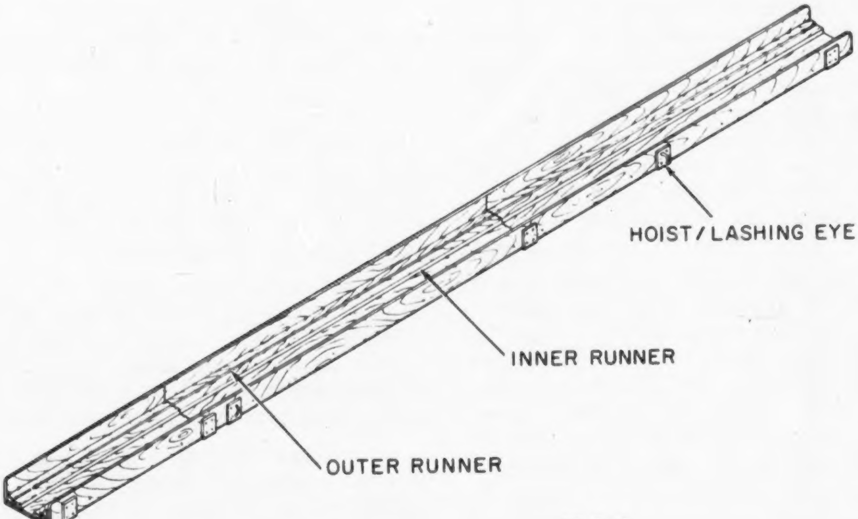
The ammunition chute, figure 11-9, consists of a plywood base and sides with inner and outer runners reinforced with steel straps. Two hoisting/lashing eyes are attached to each side to facilitate positioning and handling. The wood surfaces are treated with perservative and varnished.

The ammunition chute is used to transfer tanked and boxed destroyer type ammunition between combat ship and dockside. Cargo mats or other forms of dunnage are used at the bottom of the chute.

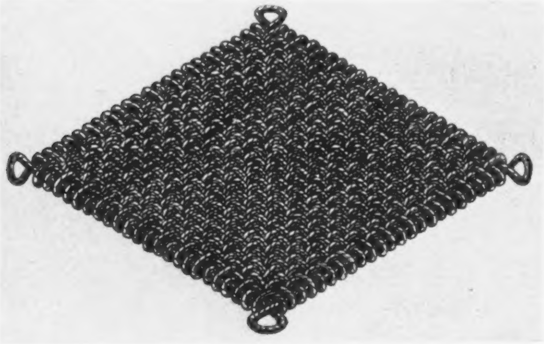
Mats

The cargo mat figure 11-10, is a closely woven mat having no openings or mesh. The mat is constructed of 3-inch coir, which is a coconut husk fiber rope. The mats come in two sizes, 6 feet square and 4 feet square. The mats have looped eyes on each corner for lifting.

The mat is used aboard ship and at shore stations. It is used also inside cargo nets or skip boxes for the protection of the cargo. It is used to cushion the landing of a draft or material which is transferred on a slide.



53.313
Figure 11-9.—Chute, ammunition.



5.61.4
Figure 11-10.—Mat, cargo.

Skip Box

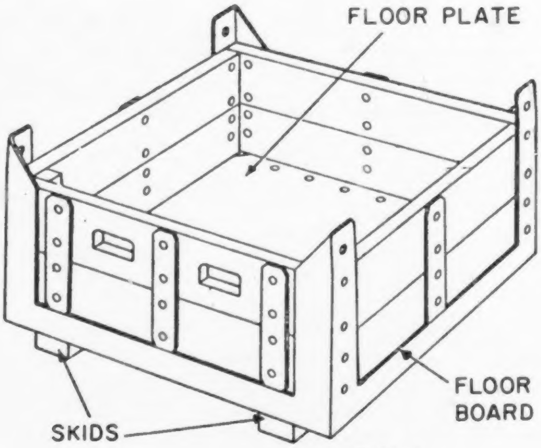
The cargo handling skip box, figure 11-11, is made of wood except for the iron corner angles and stiffeners. This type of handling device is ideal for handling ammunition that is light enough to be handled by hand. The cargo handling skip box is used aboard ship and at shore stations. The heavy timber skids underneath permit the use of fork lift trucks or slings to handle the box.

Pallet Adapter's

Top-spacer Mk 11 Mod 1 used with bottom spacer Mk 11 Mod 1, figure 11-12, makes a complete pallet adapter for handling rocket heads and projectiles. The top and bottom spacers are fabricated of steel wire. The bottom spacer has 12 recesses, each of which holds the base of a projectile. The top spacer has 12 equally spaced holders to receive and hold the noses of the projectiles in a vertical position. The top spacer is reversible, one side being for rocket heads and the other for projectiles. There is a lifting link on each side of the top spacer.

Pallet adapter Mk 11 Mod 1 is used aboard ship and at shore stations, and will handle a unit load of twelve 5-inch 54-caliber projectiles Mk 41, Mk 48, and twelve 5-inch 38-caliber projectiles Mk 35, and Mk 49. It will also handle twelve 5-inch rocket heads Mk 2 Mod 2, Mk 6 Mod 1, and Mk 25 Mods. To secure the load on 40 x 48-inch pallet, flat steel strapping should be used.

Pallet adapter Mk 16 Mod 0, figure 11-13, is a complete pallet adapter consisting of a top frame, rear frame, and front frame. It is used aboard ship and at shore stations and is capable of handling a capacity load of thirty-nine 5-inch 54-caliber cartridge tanks. To secure the load on a pallet, flat steel strapping should be used.



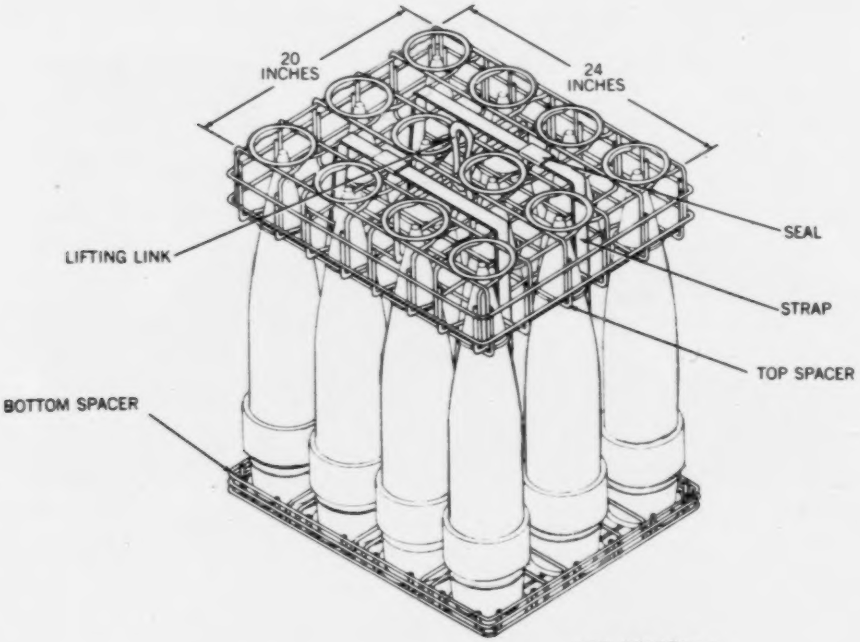
5.61.1
Figure 11-11.—Box skip.

ASROC HANDLING AND STOWAGE

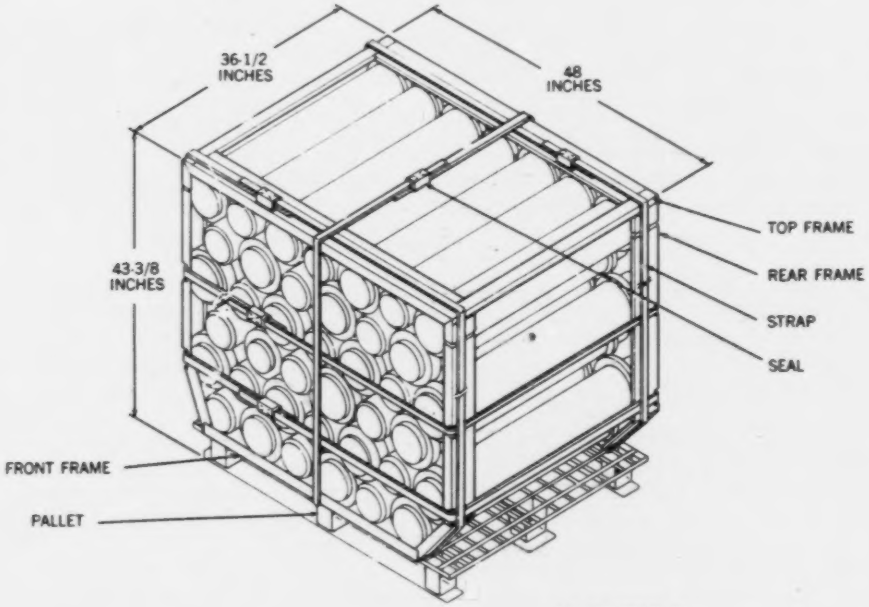
The ASROC may be either a torpedo or a depth charge. The difference in the two configurations is in the pay load, the depth charge has a nuclear warhead. The power supplies for the depth charge are packed separately but, otherwise, the missiles arrive at the firing ship fully assembled. The ASROC missile handling equipment consists of a missile loader, missile container Mk 183, two hand lift trucks, and over the side handling equipment.

Some ships have extra stowage space for ASROC missiles, but most ships stow all ASROC missiles in the eight cell launcher Mk 112. These ships use an ASROC loader crane, figure 11-14, to load or offload missiles from the guide cells to a missile container Mk 183.

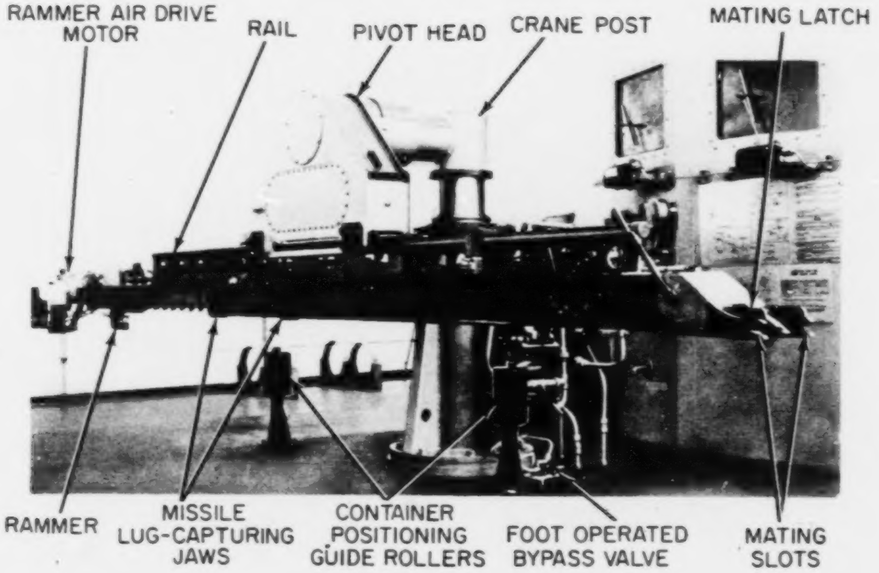
On ships having an ASROC magazine, a different type of loader is used. This loader, called a direct loader, transfers missiles from the ASROC magazine to the launcher cells or from the launcher to missile container Mk 183.


20 INCHES
24 INCHES
SEAL
LIFTING LINK
STRAP
TOP SPACER
BOTTOM SPACER

123.53(53C)A
Figure 11-12. — Adapter, pallet, Mk 11 Mod 1.


36-1/2 INCHES
48 INCHES
43-3/8 INCHES
TOP FRAME
REAR FRAME
STRAP
SEAL
FRONT FRAME
PALLET

123.53(53C)B
Figure 11-13. — Adapter, pallet, Mk 16 Mod 0.


RAMMER AIR DRIVE MOTOR
RAIL
PIVOT HEAD
CRANE POST
MATING LATCH
RAMMER
MISSILE LUG-CAPTURING JAWS
CONTAINER POSITIONING GUIDE ROLLERS
FOOT OPERATED BYPASS VALVE
MATING SLOTS

94.6
Figure 11-14.—ASROC loader crane.

ASROC Loader Crane

The loader crane (figure 11-15) is used for loading missiles into the launcher, unloading missiles from the launcher, and for removing or replacing missiles in container Mk 183. The loader crane is 143 inches high, 70 inches deep, 241 inches long, weighs 25,000 pounds, requires 100 psi air pressure, and has a maximum operating hydraulic pressure of 850 psi. The loader crane consists of the following major assemblies:

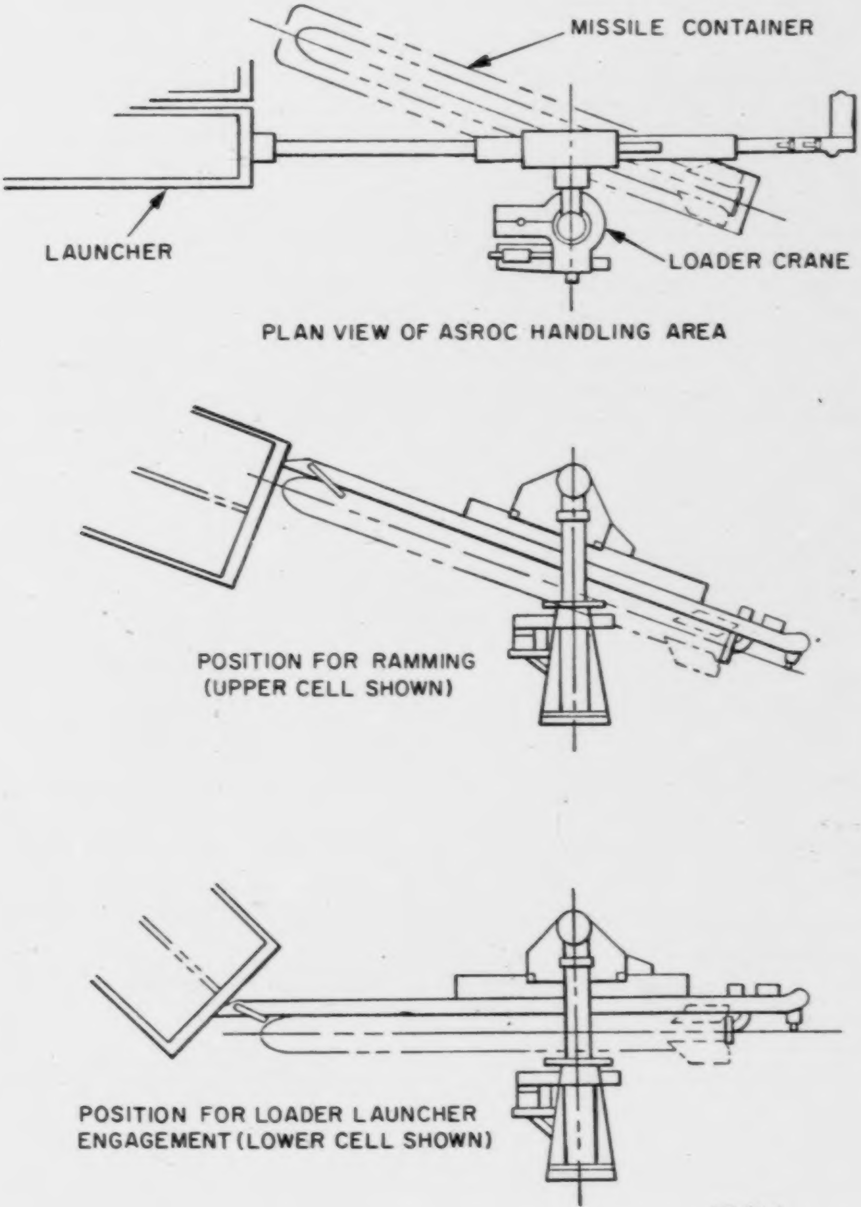
a. Electrohydraulic power unit
b. Loader crane post
c. Turning gear assembly
d. Pivot head assembly
e. Rammer rail assembly

ELECTROHYDRAULIC POWER UNIT.—The electrohydraulic power unit furnishes power to raise, lower, and train the loader crane. It consists of a reservoir on which is mounted a 10-horsepower drip-proof electric motor which, in turn, drives a hydraulic pump. The fluid in the reservoir is pumped into the system. A relief valve on the discharge side of the pump maintains a constant pressure on the system. Any excess fluid is spilled over the relief valve and returned to the reservoir.

CRANE POST.—The crane post is permanently mounted to the deck adjacent to the launcher and consists of a combination of upright concentric cylinders and pipes. The crane post raises and lowers the loader crane in response to the application of electrohydraulic power. The concentric arrangement of the hydraulic elements permits rotation about the vertical axis of the crane post.

TURNING GEAR ASSEMBLY.—The turning gear assembly turns the external cylinder of the crane post. Force is applied by a hydraulic motor governed in speed and direction by a control valve. Although possible rotation is 360 degrees, hydraulic limit stops are installed to prevent damage to ship structures. A dial, calibrated in degrees, is provided on the post around the cylinder to indicate the position of pivot head and rammer rail for launcher-loader crane alignment.

PIVOT HEAD ASSEMBLY.—The pivot head assembly is a triangular-shaped structure, attached at its apex to a cylindrical arm extending


MISSILE CONTAINER
LAUNCHER
LOADER CRANE
PLAN VIEW OF ASROC HANDLING AREA
POSITION FOR RAMMING
(UPPER CELL SHOWN)
POSITION FOR LOADER LAUNCHER
ENGAGEMENT (LOWER CELL SHOWN)

53.314

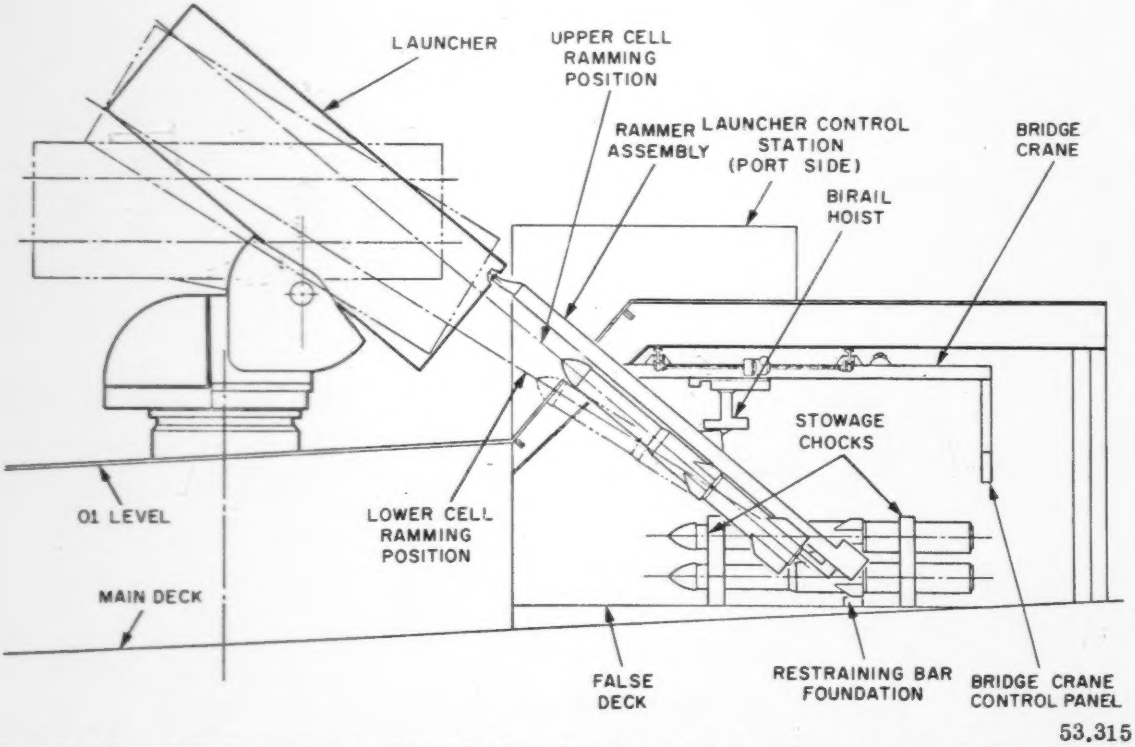
Figure 11-15.—ASROC loader crane, general arrangement.

horizontally from the crane post. The base of this structure forms the trackway upon which the rammer rail support rollers travel. The pivot head is slaved to vertical movements of the launcher when mated for loading or unloading operations.

RAMMER RAIL ASSEMBLY.—The rammer rail assembly supports, guides, and rams the ASROC missile into the launcher. This assembly is mounted to the roller trackway of the pivot head assembly. The travel motion of the rail on the trackway is controlled by a double acting hydraulic cylinder that is operated by a hydraulic hand pump. The rail is fitted with lug-capturing jaws that are operated to engage the ASROC missile lugs and are locked by a hand lever. When the jaws are locked, the loader crane is raised to lift the missile from the container. The forward end of the rammer rail is fitted with interlocking latches that secure it to the launcher. An air-driven motor at the after end of the rammer rail drives a sprocket engaged to a roller chain. This motor and chain drive rams the missile into the launcher cell to within 12 inches of its final position. At this point, air drive to the motor is automatically cut off. The ramming cycle is completed by manual operation of a hand crank attached to the air-motor shaft. The rammer rail is detached and stowed in a specially fitted rammer rail stowage compartment when the loader crane is not in use.

ASROC Direct Loader

The direct loader (figure 11-16) is located directly forward of the launcher in the ASROC magazine and is used to transfer missiles from magazine chocks or missile container Mk 183 to launcher, and unloading missiles from launcher and stowage into magazine chocks or container.


LAUNCHER
UPPER CELL RAMMING POSITION
RAMMER ASSEMBLY
LAUNCHER CONTROL STATION (PORT SIDE)
BRIDGE CRANE
BIRAIL HOIST
STOWAGE CHOCKS
01 LEVEL
LOWER CELL RAMMING POSITION
MAIN DECK
FALSE DECK
RESTRAINING BAR FOUNDATION
BRIDGE CRANE CONTROL PANEL

53.315

Figure 11-16.—ASROC magazine, direct loader, launcher, and launcher control station, general arrangement.

The loader consists of the following major units:

a. Traversing rails
b. Bridge crane assembly
c. Birail hoist assembly
d. Rammer assembly
e. Blast doors and actuator assemblies
f. Hydraulic power supply
g. Control panel

TRAVERSING RAILS.—Forward and aft traversing rails are used to support the bridge crane. The rails are secured to the overhead structure of the magazine in an athwartship position from the port replenishment door to the starboard bulkhead. Both rails consist of gear racks, stop plates, and a rail weldment. The forward rail uses deceleration and stop switches. Overtravel cams, also on the forward rail, activate the associated overtravel switches. Index switches, mounted at the four blast door positions, are operated by an index cam mounted on the bridge crane.

BRIDGE CRANE ASSEMBLY.—The bridge crane assembly is supported by the traversing rails and is capable of travel athwartships from the loader stowage position, located on the port side, to four blast door positions, and to temporary stowage and decanning positions. The bridge crane assembly supports the birail hoist and rammer assembly. The bridge crane assembly consists of a bridge structure, two roller support subassemblies, bridge crane hydraulic drive mechanism, control panel, junction box, and a spring-loaded self-winding hose reel. Hydraulic and electric power is supplied to the bridge crane by overhead-mounted reels; two are hose reels and one a cable reel.

BIRAIL HOIST ASSEMBLY.—The birail hoist assembly provides hoisting and fore and aft movement of the missile. Operating with the bridge crane and rammer assembly, the birail hoist is capable of transporting the missile from stowage chocks or missile container Mk 183 to the launcher. The birail hoist assembly consists of a hoist frame, sway braces, hoisting mechanism, two support roller bearing subassemblies, and associated components.

RAMMER ASSEMBLY.—The rammer assembly is a powered strongback used to ram missiles into or withdraw them from the launcher cells. Power is provided by a hydraulic motor and chain-driven mechanism. The rammer assembly consists of a main frame, forward lock, rails, pickup subassemblies, and hydraulic hand pump. The hydraulic hand pump is mounted at the after end of the rammer assembly and is used for ramming a missile the final 6 inches of travel into the launcher cell. The rammer assembly automatically tilts to 20° during mating with launcher and the rammer assembly is automatically positioned to horizontal during retraction from launcher. A tilt safety pin locks rammer assembly in the horizontal position to the birail hoist. This pin must be removed prior to mating with launcher, and must be replaced after retraction from launcher.

BLAST DOORS AND ACTUATOR ASSEMBLIES.—Four blast doors are located at the forward bulkhead of magazine and, when open, provide access for direct loading of missile from magazine to a selected cell of launcher. Eight hydraulically actuated dogs are provided to seal each door against rocket blast and weather penetration. Dog cams permit installation adjustment to ensure proper fitting of the door with respect to the framing. When a specific door is undogged, the hydraulic power is transfered to the rotary actuator that opens the door. A hydraulic manifold is located on the forward bulkhead and used to control the operation of the doors.

HYDRAULIC POWER SUPPLY.—The hydraulic power supply generates and controls the hydraulic power to operate the blast doors, bridge crane, birail hoist, and rammer. This supply is an integrated unit incorporating an electric motor, hydraulic pump, reservoir, and associated controls and indicators. The hydraulic system requires 28 gallons of hydraulic fluid, MIL-L-17672, Type 2135T-H.

CONTROL PANEL.—The control panel is rigidly suspended from the after end of the bridge crane structure and contains the necessary pushbuttons, switches, and levers to control all movement of the loader. The control panel contains start, stop, emergency run, and bypass pushbuttons for loader operation, and a power available indicator lamp. Three indicating lamps, LCHR ALIGNED, LCHR LOADER ALIGNED, and MISSILE SNUBBED, light when each function is completed. The control panel contains a selector switch for loader function selection, and a control lever that is positioned and held for loader operation.

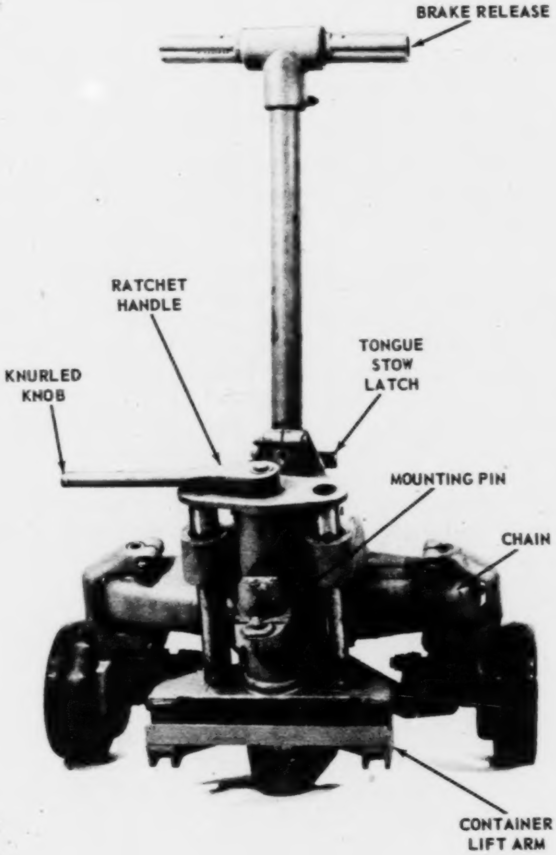
EMERGENCY MANUAL OPERATION.—In the event of power failure, manual ramming can be accomplished by using the hand pump and manual ram selector valve located on the after end of the rammer assembly. All other loader functions can be accomplished by using the hand pump located on the hydraulic power supply, and by manually actuating appropriate hydraulic directional valves. If 110 volts 60 Hz is available to the control panel during manual operation, all interlocks are effective, and the control panel can be used for directional valve operation.

Hand Lift Truck

Hand lift trucks Mk 42, figure 11-17, are manually-operated, two-wheeled dollies that are used to maneuver ASROC missile container Mk 183. The trucks contain mechanisms for steering, braking, lifting, and lowering. Two trucks with operators are required to handle one missile container, one truck at each end of the container, figure 11-18. The trucks are capable of raising a missile container approximately eight inches. The lifting mechanism is operated by a hand bar assembly equipped with two handles. The hand bar is connected to the axle for steering the truck. A reversing ratchet wrench is provided for either raising or lowering the lift arm assembly. The brakes are spring loaded and normally engaged, except when released by an operator. This prevents the trucks from rolling when there is no operator present, when a missile container is being loaded onto a hand truck, or when as ASROC missile is being removed or loaded into a missile container. The trucks should not be operated on an incline of more than 20 degrees.

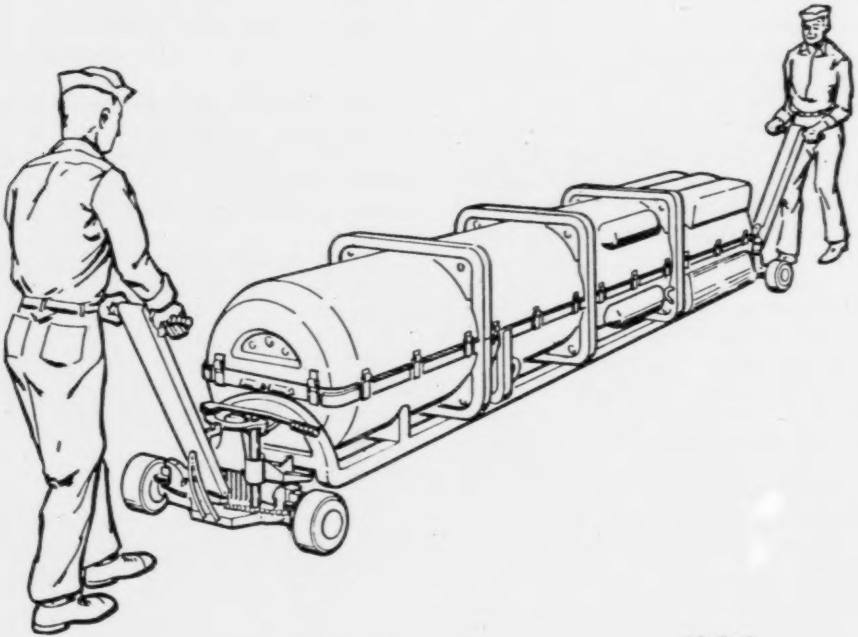
Over-The-Side Handling Equipment

The primary function of over-the-side handling equipment is to deliver ASROC missiles in missile container Mk 183 to the firing ship. This equipment normally is used to transfer a missile while a ship is in port. Only a general description of over-the-side handling is given; as individual tools, equipment, and procedures required for handling differ from ship to ship. These differences preclude procedures and, therefore, are not included as part of this publication. Normally over-the-side handling equipment is installed on the ASROC deck in the launcher and magazine area for easy transfer of the missile in missile container Mk 183 during loading and unloading operations.



94.7
Figure 11-17.—Handlift trucks Mk 42.

Generally, over-the-side handling equipment requires a king post, handling boom, handling sling(s), tending lines, and a mechanical device for raising and lowering the container. The king post is mounted on the ASROC deck into a deck socket and supported by braces. Attached to the top of the king post is the handling boom used for supporting and rotating the missile container. The tending lines are attached to the handling boom and container for stability and control during transfer. A specially designed sling is required to attach the container at the proper pickup points to ensure that the container remains level during all raising and lowering operations.



53.316

Figure 11-18.—Handlift trucks connected to container.

Handling Prerequisites

Missile handling procedures can be performed in a safe and expeditious manner only when preparations are previously completed. The prerequisites for replenishment, personnel and equipment safety, recommended personnel, and tool requirements must be met prior to beginning missile handling.

Missiles may be delivered to the firing ship while in port or at sea, using only approved methods of transfer. Over the side handling equipment is the normal method of receiving missiles in port. High line and VERTREP (vertical replenishment by helicopter) are methods of transferring missiles at sea. Approval of the transfer methods shall be verified prior to beginning operations.

Prior arrangements shall be made with the supplying activity for availability of such equipment as hand trucks, empty containers, thrust neutralizers, and shorting plugs.

If depth charge missiles are received, the firing ship will receive one power supply Mk 112 for each depth charge pay load.

ASROC Requirements

During missile handling or test procedures, safety is of paramount importance. Personnel engaged in missile handling shall never be evaluated on a competitive basis except servicing missiles for training or in action, and then only under conditions prescribed by appropriate authority.

Prior to missile handling, it is recommended that a safety briefing be conducted and attended by all personnel involved. The content of the briefing should be determined by the specific task to be performed and should consist of the following information as a minimum:

a. Applicable portions of OP 3347 (United States Navy Ordnance Safety Precautions)
b. All applicable ship and weapon department safety instructions
c. General ASROC safety precautions as follows:

Unless otherwise directed by proper authority, the Joint Chiefs of Staff Peacetime Safety Rules shall be observed.

Personnel not assigned to perform missile handling duties shall remain clear of the handling and loading areas.

No smoking or open flame will be permitted in the handling and loading area.

Safety observers shall be posted before missile handling is started. They shall enforce all pertinent safety instructions and shall not be secured from their duties until all handling procedures are completed and the handling system has been secured.

Electromagnetic radiation can ignite squibs and primers in the ASROC missile. Radio and radar transmissions must be reduced or secured in accordance with current Hazards of Electromagnetic Radiation to Ordnance (HERO) instructions. Specific ship characteristics must be studied in order to establish the various factors of electromagnetic radiation. Consideration should be given to all applicable factors, including frequency, type, power level, and physical location of antennas.

No missiles will be loaded into the launcher during initial loading (starting with an empty launcher) until a satisfactory power-on test has been performed on all cells of the launcher.

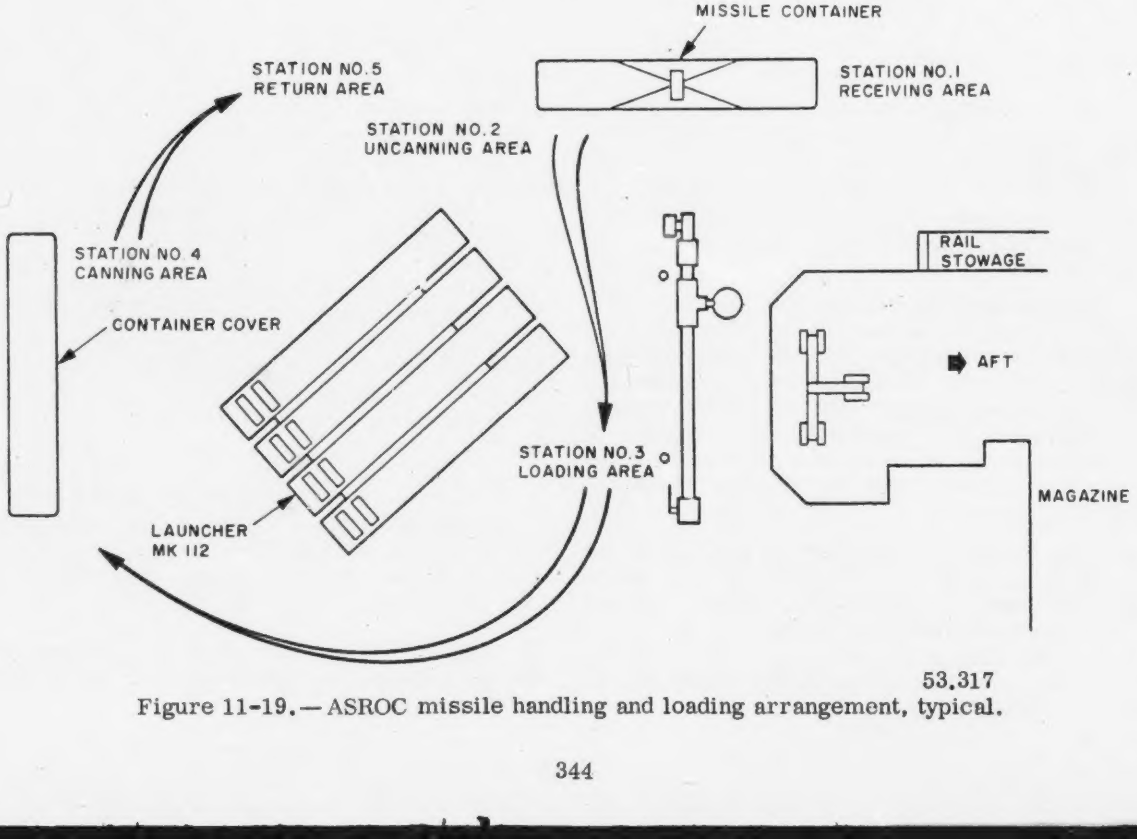
No missiles will be electrically connected to the launcher until a satisfactory power-off test has been performed on the cell. Under certain conditions, a power-off test may be required on the second cell of a guide.

All personnel must be alert to detect unsafe conditions and to apply immediate corrective action.

The ASROC firing circuit enable switch shall be set to OFF and locked except during authorized operations or test procedures.

LOADING OPERATIONS

Figure 11-19 shows a plan view of a missile handling and loading arrangement during replenishment. This view represents the typical


MISSILE CONTAINER
STATION NO.5
RETURN AREA
STATION NO.1
RECEIVING AREA
STATION NO.2
UNCANNING AREA
STATION NO. 4
CANNING AREA
RAIL
STOWAGE
CONTAINER COVER
AFT
STATION NO.3
LOADING AREA
MAGAZINE
LAUNCHER
MK 112

53.317

Figure 11-19.—ASROC missile handling and loading arrangement, typical.

deck arrangement for ships of the DD710 class and should be adjusted for the most practical routing of the missile and container on individual ships. After the missile container is disengaged from the transfer equipment, the container is moved through stations that are numbered consecutively for uncanning. The empty container, with cover replaced, is cycled through the remaining stations and back to the supplying activity. The rate of transfer should be adjusted to keep pace with the loading rate.

The loading cycle consists of receiving the missile, handling and uncanning the container, using the loader crane to pick up the missile from the container, and loading the missile into the launcher.

When receiving ASROC missiles, make a thorough visual inspection of the missile, after uncanning, and prior to loading to verify the following.

1. The missile is equipped with a thrust neutralizer and ground strap
2. The missile has not been physically damaged during transit
3. Motor fins have not been bent through improper placement or removal of the container cover
4. The missile records have been included in the attached envelope
5. All airframe separation pins (used when assembling and disassembling the missile) have been removed
6. The battery scoop lanyard wire and lanyard pin (for torpedo payloads) are aligned for a straight pull from the scoop plunger pin

When receiving ASROC missiles, be sure that you also take aboard spare thrust neutralizers, spare nose caps, and spare missile cable assemblies. When loading depth charges, you should receive a power supply for each depth charge received.

It is recommended that all preparatory operations be completed at least 2 hours before scheduled loading time. All personnel must be out of the equipment before any of the equipment is put into operation.

Checkoff Lists

At least one hour before the replenishment is to begin, prepare the loader crane and give it a careful checkout. Operate it through all the steps of loading. When the crane is not in use, the rail is detached and placed in its specially fitted stowage compartment.

The steps in making the launcher safety test, checkout for the loading crane, transfer of missiles to the launcher, loading missiles into the cells, and for securing the launcher and the loading crane after completion of operations are given in OP 2904, ASROC Weapon System for Ships with Fire Control Group Mark 111, and OP 2963, ASROC Weapon System for Ships with Fire Control System Mark 114(U) (Including Associated ASW Systems).

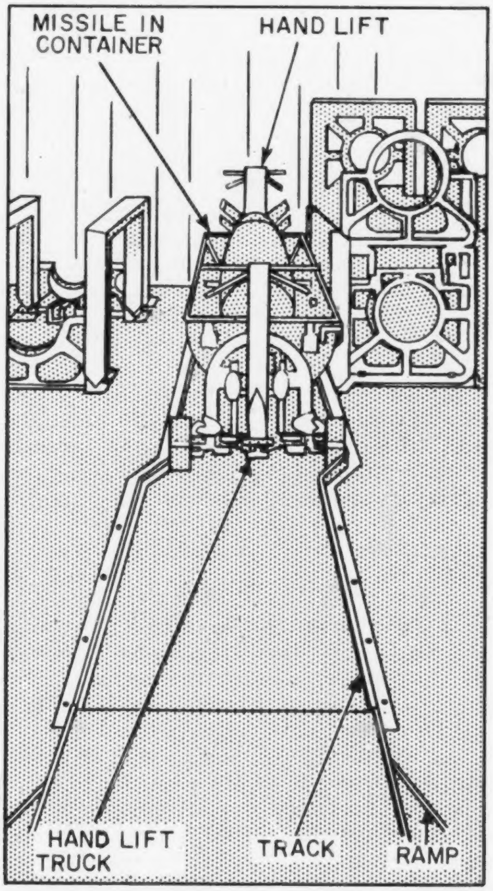
Sample checkoff lists are given in Appendix A of the above texts. Using them as a guideline, prepare your checkoff lists for the handling and stowage operations as they should be done on your ship. If your ship has a below decks magazine to hold extra missiles, or a deck magazine, you will need another checkoff list for that operation. Be sure to list the safety precautions that apply; select applicable ones from the safety summary at the beginning of the above references.

Storing ASROC in Magazines

If ASROC missiles are to be stowed in magazines, whether at replenishment or unloaded from launchers, the handling equipment in the magazine must be prepared and checked. On ships that have a loader crane in the magazine, move the loader rail out of the trolley hoist area. The operating condition and safety of the hoist must be checked out before it is used. Install the ASROC strongback on the trolley hoist. Install the portable tracks and portable ramps, bolting the sections to the deck. Check the condition of the stowage racks. The stowage plan should show which racks are to hold missiles and which ones are to hold depth charges. Those that will hold the depth charges must have the liner inserts removed from top and bottom of the forward chock. Be sure the inserts are in position for the racks that are to hold the torpedo form of the missile.

You will need two handlift trucks for handling the missile between stations when it is not attached to the loading crane or the trolley hoist. Figure 11-20 shows a missile on handlift trucks on tracks in the magazine, with stowage racks in the background.

The cover is removed from the container before the handlift trucks are attached to the container. It requires two to four men to handle the cover safely. It must be lifted sufficiently (about 18 inches) to clear the missile fins and



94.117
Figure 11-20.—Missile container position for trolley hoist pickup of ASROC.

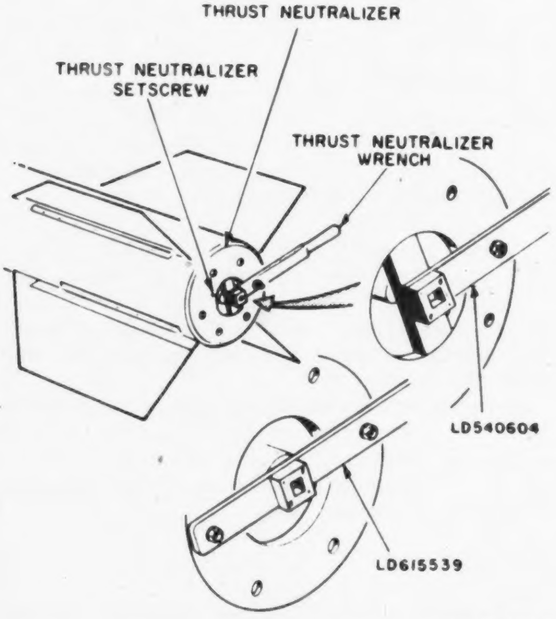
not damage them. Equal care must be used when replacing the cover so as not to damage the fins. Another caution: the covers cannot be interchanged; they fit only on the matching serially numbered container.

Do not disconnect the ground wire between the container and the thrust neutralizer in the missile until the missile is securely attached to the loader crane or the trolley hoist. Be sure all mechanical connections to the hoist are properly made and the pin locks are secured. Raise the missile with the hoist, move it over the stowage rack, and gently lower it into the rack. Be careful not to damage the nose or the fins. Attach a ground strap to the missile, and make sure the connection is good. Spacers and slides of chocks hold the missile in the rack. Position them carefully and securely. Then remove the thrust neutralizer from the missile, as shown in figure 11-21. The neutralizer is heavy and awkward to handle; take care to avoid injuring your hand while removing it. Two styles of wrenches are shown in the illustration, either of which may be used to loosen the nut on the thrust neutralizer. The removed thrust neutralizer is stowed. If a missile is to be offloaded, the thrust neutralizer must be restored to it.

The end of the missile is protected by metal forms called shrouds, placed in position after the thrust neutralizer has been removed. The empty missile container and the handlift trucks are stowed afterward in places assigned for them.

Thrust Neutralizer

The thrust neutralizer is a metal disk locked in place on the rocket motor nozzle plate. The purpose of the thrust neutralizer is to deflect the propellant gases in the event of accidental



94.31(94A)
Figure 11-21. — Removing thrust neutralizer from ASROC.

rocket motor ignition. This deflection results in neutralization of the missile's forward thrust. The thrust neutralizer remains attached to the motor until the missile is placed in the launcher, or stowed in the ASROC magazine.

Spare ASROC Component Stowage

Stowage racks specially constructed to hold spare components of the missile are provided in or near the ASROC magazine. When each shelf is properly and compactly stowed with the spare component packages and a batten placed across the access opening, the packing cases are prevented from shifting during ship motion.

Spare nose caps for depth charges and torpedoes, missile cable assemblies, flexible breech covers, and an air sampler fit compactly into the stowage racks.

Depth charge power supplies are placed in locked storage, with the keys in charge of the weapons officer.

Safety plug P1 should be kept in the possession of the officer in charge of missile handling operations, and inserted only when so directed by the officer.

Since the ASROC missile contains nuclear components, personnel handling ASROC missiles must observe all safety precautions when transporting, handling, and stowing nuclear weapons and components. As a GMGC you also are responsible for the knowledge of the criteria for safeguarding of nuclear weapons. OPNAVINST 05510-83B explains the criteria and standards for safeguarding nuclear weapons. The following paragraphs explain nuclear safety, security, and special weapons criteria.

NUCLEAR WEAPON OPERATION AND SAFETY

Nuclear weapons used by the Navy may be bombs, torpedoes, missiles, depth charges, and projectiles.

Rules for peacetime operation of nuclear weapon systems issued by the Chief of Naval Operations along with official Naval Ordnance Systems Command special weapons check lists are mandatory directives which must be followed. The operation of each type of nuclear weapon is described in the applicable Special Weapons Ordnance Publication (Navy SWOPS). Nuclear weapons will be handled and stored in accordance with Navy SWOP 50-1 and SWOP's of the 20 series. No ammunition assemblies or components shall be disassembled or modified unless authorized by applicable technical instructions. Detailed safety precautions and considerations are prescribed in Navy SWOP 50-1.

Special Weapons Publications

Special weapons publications are explained in the following paragraphs.

Joint Atomic Weapons Publications. The Joint Atomic Weapons Publications System (JAWPS) was established in December, 1964, by an agreement signed jointly by representatives of the Department of Defense and the Atomic Energy Commission. All Joint Atomic Weapons Publications (JAWP's) are assigned a Defense Atomic Support Agency Technical Publication (DASA TP) number. The short title for a specific JAWP consists of two parts: (a) a letter-numeral group which identifies the organization having an interest in the equipment described in the publications, (b) a letter and/or manual group that codes the publication to a specific subject, (OP 3347 and SWOP 0-1 lists the identifying designation for each service and agency). If the publication is not applicable to a service, the identification designation of that service does not appear. When referenced to a JAWP is necessary between any of the services or agencies, the identifying designation of DASA TP is given. However, when reference to a JAWP is within a service or agency, the applicable identifying designation is used. For example, within the Naval Establishment, a JAWP is referred to as a NAVY SWOP (Special Weapons Ordnance Publication).

Distribution of Navy SWOP's

The U.S. Naval Ammunition Depot (NAD), McAlester, Oklahoma, maintains a Navy SWOP Allowance List for each activity receiving Navy SWOP's. This allowance list is kept current by use of the Naval Atomic Planning, Support, and Capabilities (NAPSAC) Report, letter requests, and advance planning information. Periodically a review copy of the allowance list is forwarded to the activity concerned. A copy is forwarded to the type commander, where appropriate, so reference can be made to publications held by a ship. Distribution of Navy SWOP's is detailed in OPNAVINST 5511.31 series. NAD, McAlester distributes Navy SWOP's in accordance with the allowance lists, and is the stock and mailing point for all Navy SWOP's. Documents should be ordered on DOD Form 1149 (filling out the appropriate blocks in sections 1 and 2). Requests for corrections to the allowance list are prepared in accordance with OPNAVINST 5511.31 series and should be submitted in a letter form as follows: (a) Navy activities submit requests to the Commanding Officer, NAD, McAlester via appropriate commands; (b) Marine Corps activities submit requests to the Commanding Officer, NAD, McAlester via Commandant, Marine Corps. Distribution of, and request for, AEC and DASA restricted data documents shall be in accordance with OPNAVINST 5511.31 series.

Nuclear Weapons Security

The Chief of Naval Operations is responsible for regulations for the security of classified matter. Basic security measures are set forth in U.S. Navy Regulations 1948, Chapter 15 and OPNAVINST 5510.1 series. Specific references to classification policy, security of Restricted Data, security instructions for handling, transporting, and storing nuclear weapons components, and other security requirements are prescribed in the OPNAV Instruction series 5510.

Cable Assembly Mk 10

Cable Assembly Mk 10 is an electrical cable which connects the fire control system to the missile and is fitted with a quick-disconnect device so that it remains with the launcher after the missile is fired. After firing, the cable assembly is returned to a Tender for testing. A cable assembly is shipped with each missile in the missile container. One end (the single end) of the cable plugs into the receptacle of the missile's ISA (Ignition and Separation Assembly), and the other end of the cable connects to the launcher.

Cable assembly Mk 10 is frequently damaged during missile loading and unloading and during repeated connecting and disconnecting at the launcher cell junction boxes. As a result, the cable assembly must be discarded because of abuse from improper procedures.

Some cables are discarded without determining the cause of malfunction; in many of these instances, minor corrective maintenance would have restored normal operation.

To eliminate cable damage, personnel are cautioned to use the correct connecting procedures and connection diagrams contained in the missile loading procedures of OP 2904 and OP 2983. Loading personnel should remove the cable's dust covers just prior to making the cable connections, and not sooner. Corrosion may occur in the plug and receptacle connections, causing shorts or grounds at a later date, if the connectors are exposed to weather conditions. In addition, it is possible to induce current into the missile's squib circuits by shorting the pins together with your hand. In this case, the person is acting as an antenna for electromagnetic radiation. To aid correct cable connection handling, additional information is given in the following paragraphs.

The plug exterior is kept in the forward position by a strong spring, making it difficult to pull back on the plug extractor, but ensuring positive action of the plug latching arms. The keyways must be properly aligned, and personnel should proceed carefully when connecting the cable plug to the ISA receptacle to avoid breaking or bending receptacle pins, figure 11-22.

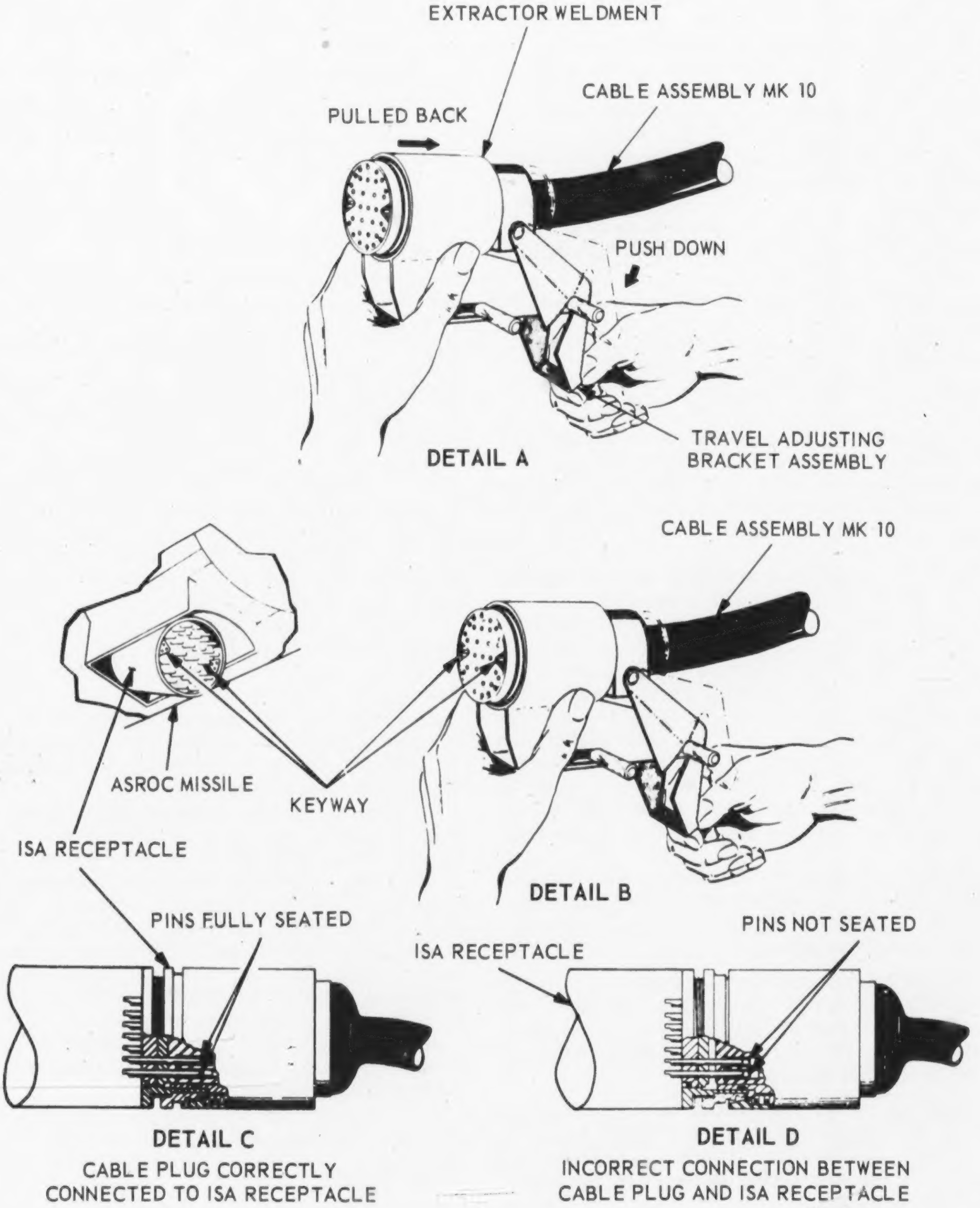
In some cases, the rubber ring on the receptacle will raise out of the groove and work back along the receptacle housing. This action prevents proper plug latching or positive electrical connection of the cable assembly.

SAFETY

Safety is an inherent responsibility of command. The organization of safety, therefore, follows the chain of command. The burden of responsibility that a commanding officer has for personnel and material under his command is recognized and allowance is made for discretionary perogative of command in response to local conditions and unusual situations.

Personnel required to handle ordnance shall be carefully and frequently instructed in safety precautions, methods of handling, and storage. No one shall be permitted to inspect, prepare, or adjust live ordnance equipment until he thoroughly understands his duties, safety precautions, and hazards involved.

Personnel assigned duties in weapon handling procedures shall receive thorough indoctrination in general safety precautions and specific procedures to be performed. This indoctrination shall be conducted prior to the start of each handling evolution.


EXTRACTOR WELDMENT
CABLE ASSEMBLY MK 10
PULLED BACK
PUSH DOWN
TRAVEL ADJUSTING BRACKET ASSEMBLY
DETAIL A
CABLE ASSEMBLY MK 10
ASROC MISSILE
KEYWAY
ISA RECEPTACLE
DETAIL B
PINS FULLY SEATED
ISA RECEPTACLE
PINS NOT SEATED
DETAIL C
CABLE PLUG CORRECTLY CONNECTED TO ISA RECEPTACLE
DETAIL D
INCORRECT CONNECTION BETWEEN CABLE PLUG AND ISA RECEPTACLE

53.318

Figure 11-22.—Connecting cable assembly Mk 10 to missile receptacle.

Periodic drills shall be conducted to provide realistic training for all handling procedures and to note and correct any unsafe practices. New or inexperienced personnel must not be permitted to work independently, but shall be under the direct and continued supervision of skilled and experienced personnel until adequate experience is acquired.

Only careful, reliable, mentally and physically fit persons shall be permitted to perform handling procedures.

Knowledge of any of the following shall be promptly reported to the immediate supervisor:

Defective ordnance, containers, or handling devices

Rough or improper handling

Willful or accidental violation of safety precautions, however slight

Familiarity with any work, no matter how dangerous, is apt to lead to carelessness. Therefore, all persons who may supervise work in connection with the inspection, care, preparation, use, or handling of ordnance shall:

Use utmost care to ensure that all regulations and instructions are observed.

Carefully instruct subordinates and frequently warn them of the necessity of using the utmost care in performance of their work. No relaxation of vigilance shall be permitted.

Explain to their subordinates the characteristics of the ordnance and other dangerous materials. They shall explain the equipment, the precautions to be observed, and hazards of fire, explosion, and other catastrophies that the safety precautions are intended to prevent.

Officers or supervisors must be alert to detect any hazardous procedures or practices and symptoms of a deteriorating mental attitude, and take timely corrective action.

Safety devices must not be bypassed or made inoperative except in accordance with approved instructions. If they are inoperable for any reason, warning signs should be used to inform everyone of the increased hazard.

Smoking is not permitted in magazines, or in the immediate vicinity of weapon handling or loading operations. Matches, lighters, or spark-or flame-producing items are not permitted in explosive areas.

Personnel engaged in handling procedures shall be limited to the minimum number required to properly perform the operation. Unauthorized personnel shall not be permitted in magazines, or in the immediate vicinity of handling or loading operations.

The output of personnel engaged in handling operations shall never be evaluated on a competitive basis except in servicing weapons for training or in action, and then only under conditions prescribed by competent authority.

Accidents of any type shall be promptly reported in accordance with current instructions.

Ordnance shall be handled and treated at all times as if it were armed.

Supervisors shall be required to maintain high standards of good housekeeping in weapon-handling spaces. Everything that is not in its place, or is not in the safest condition, increases the probability of an accident. Scrap and waste shall be promptly placed in containers designated for such material. Personal effects and clothing shall be kept in designated places.

Operations of equipment shall cease immediately on evidence of malfunction or casualty. A check shall be made to determine the cause and corrective action to be taken. The equipment shall remain out of service until repairs can be made, or until it is determined to be safe for further operation.

Changes, modification in, or additions to ordnance material or material used in connection therewith, shall not be made without explicit authority.

All weapons and complementary items shall be protected from extremes of temperature, humidity, vibration, electromagnetic or magnetic fields, and radiological exposure.

Grounding straps shall be periodically inspected, maintained in good condition, and used in accordance with applicable instructions.

Handling equipment shall be weight-tested in accordance with current directives. Visual examination shall be made immediately prior to use, and from time to time during use, to ensure that defects have not developed. Any suspected equipment shall be removed from service until repaired and tested.

Ordnance safety precautions shall be posted in appropriate locations and conspicuous warning signs placed at danger points.

SPECIFIC SAFETY PRECAUTIONS

The following paragraphs contain specific safety precautions for ASROC missile, weapon handling equipment, and closely associated equipment.

Safety precautions must be carefully observed while handling the rocket-thrown depth charge or rocket-thrown torpedo since these missiles contain high explosives.

The thrust neutralizer must be removed from each missile immediately after loading into the launcher or magazine. Should a missile be fired with the thrust neutralizer installed, personnel could be killed or injured, and equipment damaged. The thrust neutralizer must be installed at all other times except when removal is specified by appropriate directives.

The missile shall be assembled and disassembled only by a facility having an assembly capability.

It is especially important that personnel are fully under cover when the missile motor ignites to avoid being struck by the metal nozzle closure seals that are blown out at dangerous velocities from the motor.

Reduce radio and radar transmission to a minimum, consistent with existing doctrine, because electromagnetic radiation can ignite squibs and primers in missile.

Open cover latches of missile containers with handhooks. Each latch is spring-loaded and snaps open with sufficient force to injure fingers.

Do not set depth charge ARM-SAFE switch to the ARM position, and do not install depth charge power supply until so directed by proper authority. Power supplies shall be stowed in a safe-type container that has an approved combination lock.

Do not disconnect ground wire between missile container and thrust neutralizer until missile is attached to loader crane or trolley hoist.

Use extreme care in handling thrust neutralizer. The shape and weight of the thrust neutralizer create a potential safety hazard.

Do not connect a missile to the launcher before the power-off test is made because stray voltages can cause an inadvertent firing.

Keep missile electrically grounded during storage.

Keep missile away from rain, salt spray, physical shock, and heat to avoid damage to missile or ignition of the rocket motor.

The rocket motor propellant becomes brittle and subject to damage by shock when exposed to low temperatures. Operations should be suspended when ASROC missile will be subjected to temperatures and exposure times beyond those listed as follows:

Exposure Time	Ambient Temperature (degrees Fahrenheit)
7 hours	+20
5 hours	+ 5
3 hours	-20
2 hours	-65

Missile should not be exposed to temperatures above 120 degrees Fahrenheit. Missile stowage at high temperatures is detrimental to the long-term safe life of the rocket motor propellant.

Observe all Joint Chief of Staff Peacetime Safety Rules for Peacetime Operations with the ASROC/Mk 44 missile system and launching group Mk 16.

Cable assembly Mk 10 shell must be kept clear of ISA connector pins. Do not touch cable connector pins with the fingers.

Do not touch ISA connector pins with the fingers.

Keep dust covers on the Y-end of cable assembly Mk 10 until missile is loaded into the launcher.

Safety plug P1 must not be installed unless so directed.

Loader Crane

Observe the following safety precautions when operating the loader crane:

Ensure that handcrank is removed from rammer air-drive motor before applying air to the rammer motor. The crank will rotate at high speed and can result in serious injury to personnel.

Do not disconnect ground wire between thrust neutralizer and container until missile is attached to the loader crane.

Before dismantling any part of the hydraulic or pneumatic equipment, ensure that the part is shut off from pressure and that pressure has been bled.

When operating any control valve from neutral to any other position, do so slowly to prevent activating equipment at high speed.

Do not use the constant delivery pump or the hand hydraulic pump to develop test pressures in excess of their designed relief valve pressure.

Do not introduce water into the hydraulic or pneumatic systems under any circumstances.

Magazine

Observe the following safety precautions pertaining to the magazine:

Magazine doors shall be closed at all times when work is not being performed in the magazine.

Naked lights, matches, or other flame-producing apparatus shall never be taken into the magazine when it contains explosives.

All explosives shall be removed to a safe storage area before performing any work that may cause abnormally high temperatures.

Magazine exits must not be blocked.

Only authorized personnel shall be permitted to enter the magazine. Personnel shall be allowed in the magazine only at such times as required by their duties. All keys to locks and locking devices associated with safety and security of the ASROC system shall be under control of the commanding officer.

Only approved electrical equipment shall be used or installed in the magazine.

Unattended magazines shall be kept closed and locked. The FZ alarm system shall be activated as directed.

The magazine shall be kept clean and dry at all times. Nothing shall be stored in the magazine except missiles, containers, and other authorized equipment. Oily rags, waste, or other foreign materials susceptible to spontaneous combustion shall never be stored in the magazine.

Do not start missile handling operations in the magazine until assured that safety observers are stationed as directed.

SPECIAL HANDLING REGULATIONS FOR BULK EXPLOSIVES AND GUN-TYPE AMMUNITION

Extreme care must be taken in handling black powder, smokeless powder, or other bulk explosives since they are highly flammable and sensitive to friction, shock, sparks, heat, and static electricity. Only non-sparking tools shall be used to open containers of these explosives. The special handling instructions prescribed in the paragraphs that follow shall be observed when handling gun-type ammunition.

Projectiles

Loaded projectiles, whether unpacked, grommeted, crated, palletized, or packed must be carefully handled and stored to avoid detonation or damage to rotating bands, bourrelets, points, caps, windshields, covers, fuze threads, painting, and identification markings. They should be handled by trucks, carriers, and slings. When rolling is the only available means for moving, protect projectile bodies, windshields, and copper rotating bands and guard against arming the fuze assembled in the projectile.

Projectiles shall not be rolled on the ground, concrete floors, or steel decks but they may be rolled on dunnage boards not less than one inch thick.

When a loaded and fuzed projectile is dropped five feet or more, it shall be set aside, tagged, and turned in to an ammunition activity at the first opportunity or dumped in deep water at the discretion of the commanding officer.

Projectile handling slings that support part of the weight of the projectile on the cap or windshield shall not be used on armor-piercing projectiles or on common projectiles fitted with windshields.

Never slide projectiles down a slide without using a restraining line. The base of the projectile should be toward the lower end of the slide.

Detonator, fuze, booster cavities, and fuze threads shall be kept free of all foreign material except for a light film of specified lubricating preservative.

Powder Tanks and Cartridge Tanks

Powder tanks containing bag charges shall not be rolled or dropped. Necessary handling operations shall be performed by carrying the filled tanks by hand, lift truck, or hand truck, being careful to prevent internal movement and possible ignition of the charge within the tank by static electricity. When lifting and moving such tanked charges, the bottom of the tank shall be held lower than the top at all times.

Tanks containing fixed cartridges or separate loaded propelling charges should be handled carefully to prevent misalignment damage to the round or destruction of close tolerance dimensions. They may be handled with roller conveyors, chutes, or trucks as long as precautions against shocks are observed. Care shall be exercised to avoid denting the thin-walled body, opening the body seams, or loosening the top or bottom rings, thereby permitting exposure of the powder to the atmosphere.

When a tank containing a fixed cartridge is dropped a distance of five feet or more, the tank and its contents shall be set aside, carefully marked, and turned in to an ammunition activity at the first opportunity or dumped in deep water at the discretion of the commanding officer.

Explosive Components

Fuzes, boosters, and detonators are loaded with explosives which are sensitive to shock, heat, and friction and must be handled with care at all times.

Every effort should be made to keep component containers sealed airtight when so packed and to expose them to the atmosphere for as short a time as possible.

Containers of explosives or blasting caps and fuzes shall not be left uncovered and must be in the custody of authorized personnel at all time.

Wooden containers in which explosive components are packaged shall be opened carefully using only approved spark-resistant tools. A wire, nail, or sharp instrument never should be used to pry open the container.

Small Arms

It cannot be emphasized too strongly that inadvertent and improper use of small arms and small arms ammunition has resulted in numerous casualties. Invariably the basic cause of each casualty is CARELESSNESS.

Cartridge cases shall not be polished, but corrosion, moisture, and dirt should be wiped off. The ammunition shall be protected from shock which might dent it or fire the primer.

Ammunition shall not be broken down except to make necessary examinations or when preparing ammunition for target practice or action. Small arms ammunition shall not be opened until the ammunition is required for use. No reworking, overhaul or modifying of any live-loaded ammunition or component is permitted on shipboard.

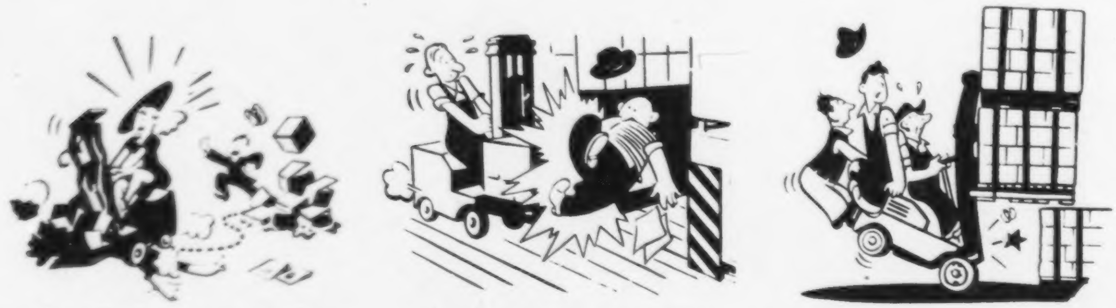
SAFETY PRECAUTIONS FOR INDUSTRIAL HANDLING EQUIPMENT

The safety precautions and instructions pertaining to the safe operation and use of ammunition and explosives handling equipment prescribed in this section NAVORD Instruction 5100. 1A, OP's 4, 5, 1014, 3347, and the applicable safety manual for the weapons shall be strictly observed, where applicable, by all naval activities afloat and ashore.

Fork lift trucks, pallet trucks, platform trucks, crane trucks, and warehouse tractors and trailers are here classed as industrial materials handling equipment which are used in various ammunition and explosives handling operations. This type of equipment is designed to save time and labor involved in handling operations. However, improper and careless operation or use of this type of equipment causes accidents which result in fatal or serious injury, damage to valuable supplies and equipment, and reduction in the efficiency of the handling operation. Therefore, it is imperative that the safety precautions and instructions prescribed for all kinds of industrial materials handling equipment be followed. Various safety tips pertaining to the operation and use of industrial materials handling equipment are illustrated in figure 11-23.

Operation of Equipment

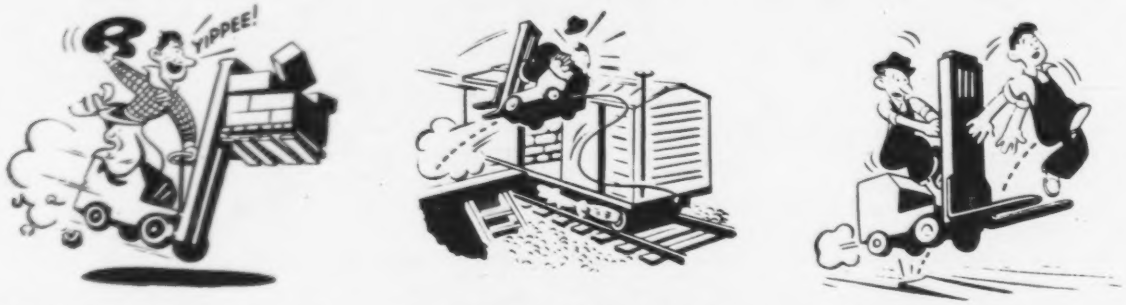
1. Only qualified personnel who have been properly trained to operate industrial materials handling equipment shall be permitted to operate such equipment.
2. Always inspect the equipment's brakes, steering apparatus, horn, fire extinguisher and other safety devices and controls before and periodically during use of the equipment. Report any defect immediately to the supervisor.
3. Always be alert for pedestrians, vehicles, and all traffic signs.
4. Never operate the equipment at a speed in excess of five miles per hour or as locally posted on traffic signs.
5. Always slow down and sound horn before crossing intersecting aisles or approaching blind corners.
6. Always slow down when approaching danger points such as downgrades, curves, blind corners, narrow travel areas, oily floors, railroad tracks, and other rough travel surfaces.
7. Never tow freight cars with the equipment as they will end up towing you.



NEVER PERMIT UNAUTHORIZED PERSONS TO OPERATE FORK TRUCKS.

SOUND HORNS OR WARNING GONGS AT ALL BIND INTERSECTORS.

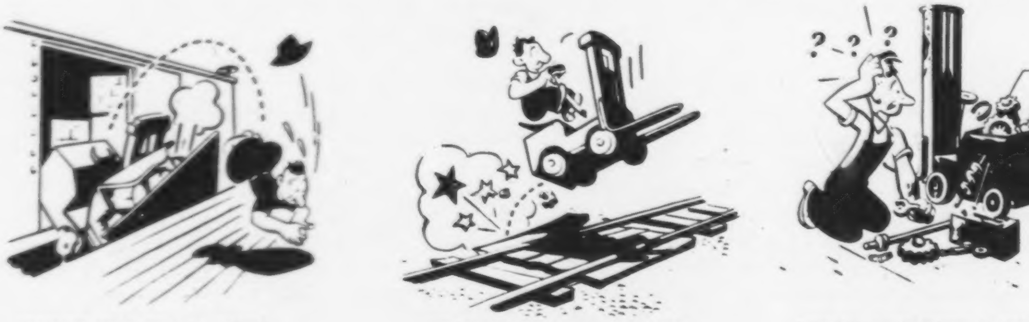
DON'T OVERLOAD YOUR TRUCK. . . LIGHTEN LOADS INSTEAD OF COUNTER WEIGHTING.



DON'T "COWBOY" YOU TRUCK. . . REPAIRS ARE COSTLY.

NEVER TOW FREIGHT CARS WITH FORK TRUCKS. . . THEY'LL FINISH BY TOWING YOU.

RIDING ON FORK IS DANGEROUS. . . DON'T PERMIT IT ON YOUR TRUCK.



CHECK BRIDGE PLATES FREQUENTLY. . . BE SURE THEY'RE SECURE.

DRIVE S-L-O-W-L-Y OVER RAILROAD TRACKS AND ROUGH SURFACES.

DON'T ATTEMPT "MINOR" REPAIRS. . . CALL A QUALIFIED REPAIRMAN.

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Figure 11-23.—Use of equipment.

8. Avoid making sudden or jerky stops by jamming the brakes on.
9. Never permit other persons to ride on the equipment.
10. Always keep well inside the operator's space, making sure your feet and arms are inside the running lines of your equipment.
11. Always watch low or narrow clearance travel areas and be sure the equipment will safely pass through such areas.
12. Avoid driving too close to the edge of platforms.
13. Never drive over bumps or sharp objects; remove them or drive around them.
14. Never "cowboy" your equipment or race another operator with your equipment.
15. Always keep three equipment lengths behind other equipment in front of you.
16. Never leave your equipment without shutting off the ignition and setting the brakes.
17. Always observe all local safety rules and regulations.
18. Always report all accidents, no matter how slight, to your supervisor.
19. Always face in the direction that the equipment is moving.

STEVEDORING AND TRANSFER-AT-SEA EQUIPMENT.—Cargo nets should not be used alone for handling thin-walled ammunition items. A rigid platform or base upon which the ammunition can be stacked should be fitted into the net. The platform should be placed as near the exact center of the net as practicable so that the load will hand level when suspended. The platform should be of such size that the net will extend well up around the load when hoisted. A heavy canvas should be placed inside wire rope cargo nets to prevent sparks and to protect the ammunition. Hooks used in handling ammunition should be moused to prevent accidental unhooking. A snap-type cargo hook may be used in handling ammunition. Never exceed the safe working load of cargo hooks, chain falls, and highline trolley blocks.

LOADING AT NIGHT.—Live ammunition and explosives shall not be loaded on or discharged from a ship or lighter at night except in an emergency or at adequately lighted piers equipped with fire protection and safety equipment and then only when required by the vessel's sailing schedule or as authorized by the Naval Ordnance Systems Command. This restriction does not apply to ammunition replenishment underway at night.

MINIMIZING HANDLING OPERATIONS.—Handling of live ammunition shall be kept to a minimum to reduce the chance of accidents and to prevent damage to containers, powder bag charges, tanks and missile sections, cartridge cases and similar material. Ammunition shall be handled carefully to avoid obliteration or defacement of the identification markings. Ammunition and explosives shall not be handled unless the items are specifically identifiable and the hazard characteristics are known. Every precaution shall be taken to avoid contact of explosives and ammunition with sand, earth, gravel, or other spark-producing substances. If explosives spill from a leaky container, all handling operations shall be stopped until the spilled explosive has been completely removed from the scene.

EXPLOSIVE ORDNANCE DISPOSAL.—Any ordnance that cannot be specifically identified shall be handled only by Explosive Ordnance Disposal personnel. The detection, rendering safe, recovery, and disposal of non-nuclear explosive ordnance which has been damaged, fired, or dropped, or which has deteriorated so it constitutes a hazard to installations, personnel, or material is considered beyond the capabilities of personnel assigned to routine disposition. Responsibilities for disposal of non-nuclear explosive ordnance are contained in OPNAV Instruction Series 8027.6.

CHAPTER 12

AMMUNITION TESTING AND SURVEILLANCE

In wartime when ammunition is needed, it is needed quickly and in a usable condition. The time to assure that these conditions will be met is, of course, prior to the need. Proper surveillance, testing, and handling are important in assuring that ammunition will be ready for use when it is needed. Personnel in the GM ratings should be trained to look for obvious but important defects while handling ammunition preparatory to its firing or when ammunition is loaded or off loaded from a combat ship.

Surveillance as used in this chapter means the examination and tests which are necessary to determine the suitability of ammunition and explosives for their intended purpose and their safe use. Examination of ammunition means the inspection of gun ammunition for signs of defects such as broken powder bags, loose or broken projectile caps or windshields, fixed ammunition projectiles loose in cartridge cases, cracked cartridge cases, and loose primers or fuzes. For pyrotechnics, demolition charges, rocket, and projector ammunition, surveillance consists of maintaining proper stowage and packaging conditions.

Testing as used in this chapter means the methods used to prepare rockets, projectors, pyrotechnics, demolition charges, and missile ordnance for firing. Since ASROC is a GMG responsibility and the ASROC missile contains both nuclear and conventional ordnance, the test requirements for Navy Technical Proficiency Inspection (NTPI), Nuclear Weapons Acceptance Inspection (NWAI), and Technical Standardization Inspection (TSI), as well as the meaning and significance of peacetime safety rules, will be discussed.

SURVEILLANCE OF SMOKELESS POWDER

Smokeless powder, being less stable than other munitions, requires a more extensive surveillance program. However, NAVORD Instruction 8020.9 directs that all previous phases of the Smokeless Powder Surveillance Program conducted afloat be discontinued. Until further notice, all surveillance testing of smokeless powder will be conducted at designated ammunition activities ashore. This means that the visual examination of magazine powder samples, violet paper tests, and surveillance oven tests that were formerly an important part of the Gunner's Mates' daily routine have all been suspended—possibly for all time, depending on the success of the new test program as outlined in NAVORD Instruction 8020.9.

This does not mean, however, that the shipboard Gunner's Mate can now relax his vigilance over smokeless powder. Smokeless powder is still unstable and potentially dangerous under adverse stowage conditions. It continues to be the Gunner's Mates' responsibility to ensure that stowage conditions for smokeless powder are maintained at a level consistent with the great importance of meeting all the special requirements for safely stowing this type of ammunition.

This includes taking the necessary steps to keep the magazine within safe limitations of temperature range. Safe limitations and control measures were explained in chapter 11. The magazine must be kept clean and dry at all times, and inspected daily to check and record the temperature and to look for any abnormal conditions such as dripping water or oil, loose powder tank lids, and evidence of loose or improper stowage.

So that you may better understand the greater need for care and vigilance with smokeless powder, the following account on its background, manner of manufacture, and general characteristics, is included in this chapter.

BACKGROUND

Before smokeless powder was adopted for use in the United States Navy, black powder was the jack-of-all-trades in explosives. It served as propellant, igniter, bursting charge, and fuze. Black powder was used for all these purposes not because it was best suited for them, but because until well into the nineteenth century it was the only practical military explosive that was known.

As a propellant, however, black powder left much to be desired. When it burned, its dense black smoke made a convenient aiming point for enemy fire; at the same time it impeded the gunner's vision. At night, its brilliant muzzle flash momentarily blinded the gun crew, and clearly showed the gun's location, so as to make it an easier target. Black powder's overfast burning rate — approaching high order detonation—made it necessary to have excessively massive gun tubes with bulbous breeches to withstand its shattering impact; yet this same high burning rate reduced its total effectiveness as a propellant. After firing, it left quantities of solid residue fouling the bore; at the same time, its high burning temperature caused rapid erosion of the bore. And, though it was stable enough to last indefinitely if kept dry, it was sensitive and therefore difficult to store and handle safely.

As a propellant, smokeless powder is superior to black powder in most of these respects. It burns slowly enough to provide optimum thrust on the projectile, thus permitting higher muzzle velocities and much more economical gun designs; it causes less erosion and powder fouling; as its name implies, it produces less smoke (though it is not 100 percent "smokeless"); and it produces less muzzle flash. Besides, constant research is going on to improve it, especially with regard to flash, burning temperature, and stability.

Yet, with all these real advantages, smokeless powder is not the ideal propellant. Its introduction resulted in improved propellant performance, but it brought some new problems, most of them concerned with the fact that smokeless powder is essentially unstable. This is something that the old-time Gunner's Mate scarcely had to worry about. Black powder, provided it is kept dry, has almost unlimited stability, but smokeless powder contains an unstable substance that causes the powder to deteriorate in storage. This lack of stability creates problems in surveillance for the Gunner's Mate.

How Smokeless Powder Is Made

It will help you to understand why smokeless powder behaves as it does if you know something about what it is made of and how it is manufactured. It is not possible in this manual to go into too much technical detail on its chemical composition and manufacture; refer to OP 4 for that. The following is a brief summary.

The raw materials used in making smokeless powder are cellulose, nitric and sulfuric acids, ether, ethyl alcohol, and diphenylamine.

CELLULOSE is a plant product. It is the main ingredient in wood and in vegetable fibers like sisal, hemp, flax, and cotton. Any of these can be used in powder manufacture — even wood — but in this country at the present time powder is made using cotton.

A mixture of SULFURIC and NITRIC ACIDS acting on the cotton performs the main chemical transformation of innocuous cotton into a high explosive.

A mixture of ETHER and ETHYL ALCOHOL (grain alcohol) is used as a solvent for the acid-treated cotton.

DIPHENYLAMINE serves as a stabilizer for the powder. This it does by reacting with the acid-forming gases produced as the powder deteriorates. These, if not absorbed, encourage further deterioration; thus the presence of diphenylamine slows down deterioration. It does NOT completely stop deterioration.

The first step in processing the cotton is to purify it. This is a fairly elaborate operation, which begins with cleaning seeds and other visible impurities out of the cotton, and continues with boiling it in sodium hydroxide (lye) solution, washing, chemical bleaching, and more washing. Since cotton purified this way is used in a number of industries besides powder manufacturing, purification is often accomplished by specially equipped plants before the cotton is even delivered to the powder plant.

When purified, the cotton is ready for the first step in actual powder manufacture — treating it with a mixture of sulphuric and nitric acids. This treatment, termed NITRATION, yields an explosive compound called PYROCELLULOSE (PYRO for short) or NITROCELLULOSE. (It may have still another name—guncotton.) Then the pyro is beaten to a pulp by machines, so as to break up the cotton fibers, further purified, and dried in big hydraulic presses which pump alcohol into it and mold it into large blocks. The blocks next go to "block breaker" machines which break them up so that the pieces can be inserted into mixing machines which knead them and add to them an ether solution containing diphenylamine.

Then the powder is again pressed into blocks, which are squeezed through a "macaroni" press that converts the blocks into long solid macaroni-like strands. (As you can guess, the point of all this breaking, mixing, purifying, molding, and so on is to eliminate entirely the original fibrous structure of the cellulose in the cotton, and to make pyro a completely amorphous or structureless mass.) Once more, the strands are pressed into a block, and at length the powder is forced, for the last time, through a die which squeezes it out or extrudes it as a perforated cord of circular cross section. The cord goes through a grain cutter which cuts it into grains of uniform length.

By now the powder looks pretty much as you see it in figure 12-1 but it is still soft and "green," because it contains too much of the ether and alcohol solvents. So it goes next to "dry houses", where excess solvents are dried out—a 2 to 3-month process. After drying, the powder is blended with other batches of similar powder to make up an index. Samples from the index are made into charges and proof fired to check its performance. After the index has been formally accepted by the Navy, it is assigned an index number and is ready for issue to the fleet.

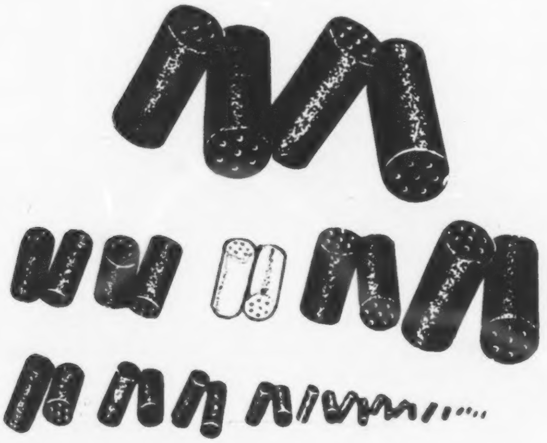

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Figure 12-1.—Smokeless powder grains, calvary .30 to 16''/50. The two white grains are SPCG powder.

Characteristics and Identification of Smokeless Powder

Each index is assigned to one caliber (sometimes to more than one, if it is suitable) and is used to make up propellant charges, with a definite weight for each charge, as determined by projectile used and muzzle velocity desired. Index numbers are assigned serially, No. 1 having been the first. The number itself can tell you nothing about the powder except its approximate age, but the group of letters preceding the numerals identifies the powder in more detail as follows:

SPD. The letters SP stand for pyro-type smokeless powder. That the smokeless powder is stabilized by addition of diphenylamine is indicated by the letter D.

SPDN. Stabilized smokeless powder, with the addition of certain nonvolatile materials that reduce the tendency of smokeless powder to absorb and retain water. This tendency is termed HYGROSCOPICITY. Powder treated to prevent it is called NONHYGROSCOPIC, and ammunition containing such powder is often referred to as NH.

SPDF. Stabilized flashless powders, in which muzzle flash is reduced by addition of potassium salts or other chemicals.

SPDW. Reworked powder, made from ground stabilized smokeless powder.

SPDB. A blend of stabilized smokeless powders, to utilize small remnants of other indexes for target practice use, or to provide an index large enough for a ship's service allowance.

SPCG. This propellant, though relatively new to the U.S. Navy, is similar to the British powder "Cordite." It differs in composition and color from the other smokeless powders listed above, which contain but one explosive component — pyrocotton — and are therefore termed SINGLEBASED. SPCG, is termed a MULTIBASE powder, containing three main explosive components. These are NITROGUANIDINE (55 percent), NITROCELLULOSE or pyrocotton (19 percent), and NITROGLYCERINE (18.7 percent), which, you remember, is the active agent in dynamite. The remaining 7.3 percent is the stabilizer, called CARBAMITE or ETHYL CENTRALITE. In spite of containing three powerful explosives rather than just one, SPCG is a lot more stable than

SPD powders because it contains much more stabilizer, much less of volatile solvents, and much less of the relatively unstable pyro.

SPCG is made in the same grain sizes and perforations as SPD powders, and gives similar performance. In general, SPCG is handled like and is governed by the same regulations as other smokeless powder, except for surveillance (oven) tests.

In this chapter, the term SMOKELESS POWDER refers to diphenylamine-stabilized (SPD type) powder, unless SPCG is specifically designated. New designations are added to the list above as new types of powder are developed. SPCG is the most recent addition. In the past there have also been powder indexes designated SP (smokeless powder without stabilizer) and SPR (smokeless powder with a chemical that indicated powder stability by changes in color), but none of these are now in service.

Smokeless powder grains (diphenylamine-stabilized type) as they come out of the cutting machine are light ivory in color. After they have been dried, they are usually amber and somewhat translucent. As the powder ages, it becomes dark brown, then black and opaque. These color changes do NOT indicate any significant loss of stability. Reworked powder may be dark brown or black to begin with. Powder in good condition has a hard, smooth horn-like finish.

SPCG is chalk-white and opaque when new, and yellows slightly with age. After prolonged deterioration has set in, SPCG darkens to brown and tends to scale off. However, SPCG deteriorates much more slowly than diphenylamine-stabilized powder.

HOW SMOKELESS POWDER DETERIORATES.—As it ages, smokeless powder undergoes changes that eventually make it dangerous to store and use. The speed of this deterioration depends largely on the conditions under which the powder is stored. Mere age does NOT necessarily imply deterioration. The main reason for periodic inspection and testing of smokeless powder is NOT to find out whether the powder is old or not, but to determine whether it is safe to store and use.

Chemically, the aging of smokeless powder can be described as a process of slow decomposition or breaking up of the compounds of which it is made. The burning of the powder is mainly a similar process of decomposition, but at a much higher rate.

As explained earlier in this chapter, the products of this decomposition have an acid reaction which increases the rate of further decomposition. The diphenylamine stabilizer found in all present smokeless powder (except SPCG) slows down this breaking-up process by absorbing its products as they are evolved. But the stabilizer does not and cannot halt the breaking-down process. In any event, this can go on for some time before the powder becomes dangerous to store and handle. It is the function of surveillance-oven tests to indicate the rate and extent of deterioration.

But why does partial decomposition of its nitrocellulose make powder dangerous to store?

To answer this question, let us examine the decomposition process in more detail. The main product of decomposition of nitrocellulose is an oxide of nitrogen which, upon exposure to the oxygen in the air, is further oxidized to produce the corrosive reddish-brown nitrogen dioxide fumes that you associate with badly deteriorating powder. Powder decomposition also produces heat. When, as in badly deteriorated powder, decomposition is going on at an accelerated rate in a sealed powder tank or cartridge case, the heat of decomposition and the increased pressure of the gases produced may, in combination, cause the powder to ignite. That is why partly decomposed powder is unsafe to store.

But decomposition of nitrocellulose isn't all that can happen to smokeless powder. It can also lose its volatile components by evaporation. Though this loss does not make it dangerous to store, one serious effect is to make the powder BALLISTICALLY unsafe, by increasing its rate of burning when fired to such a point that dangerous chamber pressures are developed. This is why it is so important to be sure that smokeless powder propelling charges are always in SEALED powder tanks until just before firing, so that the volatiles will not escape.

VISUAL SURVEILLANCE PROGRAM AFLOAT

The visual surveillance program serves as a positive safety check on the current condition of ammunition afloat and provides a valuable source of information in support of the quality evaluation program for determining continuing serviceability of Navy-wide stocks of ammunition.

Tests Discontinued

Surveillance tests of ammunition afloat have been discontinued in the interest of safety, economy, and uniformity of valid test data. Fleet unit firing reports, malfunction reports, new item operational evaluation test results and the like provide acceptable inputs to the thorough Navy-wide surveillance test program conducted continuously in laboratories ashore.

Daily Visual Inspection

Afloat surveillance now consists generally of conducting daily visual inspections of magazines for improperly secured stowage, unsatisfactory protective packaging, unusual fumes or odors, and any other abnormal conditions in the stowage spaces. Abnormal conditions in a ship magazine or ammunition stowage space include evidence of temperature humidity fluctuations; the presence of unauthorized materials; evidence of localized overheating from adjacent compartments on decks, bulkheads, and overheads; indications of leaks from sprinkler or flood pipes, nozzles, or control valves and regulators; and inoperable or damaged reach-rods, linkages, automatic fire alarm devices and other similar equipment installed in the specific hazard stowages.

Responsibility for Surveillance

Commanding officers of ships are responsible for the surveillance, accounting, and expenditure of all ammunition and explosives on board in strict accordance with Navy Regulations and NAVORDSYSCOM instructions. Navy Regulations spell out the responsibilities of ship commanding officers regarding safety of the ship and its personnel. Procedures for visual surveillance of the various types of ammunition are promulgated to units afloat in ordnance pamphlets and NAVORDSYSCOM instructions and publications. An officer or other qualified individual of the gunnery/missile department shall be assigned responsibility for administering a careful, accurate, visual surveillance program in accordance with existing directives.

Training and Rotation of Personnel

All personnel whose duties include inspection of stowage spaces and the various types of ammunition shall be thoroughly trained to perform their duties, especially in the special procedures required for surveillance of new or experimental ammunition received aboard ship. An up-to-date file of information concerning the surveillance program shall be maintained for frequent review by surveillance personnel as a part of their training. Personnel should be rotated to the various surveillance program duty assignments to keep them from becoming careless because of overfamiliarity with procedures and to provide them with additional training experience.

Uniform Methods In Visual Surveillance Programs

Surveillance procedures shall conform strictly to existing regulatory instructions to ensure safety of the ship and to standardize the surveillance program throughout the forces afloat. Since the visual surveillance program is intended to prevent deterioration of ammunition, when possible, and to detect normal unpreventable deterioration at the earliest possible time, a standardized program is essential to generate valid data for use in predicting the future serviceable life of entire lots of ammunition. The results of all shipboard surveillance programs are correlated with quality evaluation tests conducted ashore under the cognizance of NAVORDSYSCOM to determine conditions of Navy-wide stocks of ammunition.

Surveillance of Black Powder. — Black powder normally is stable in storage; however, it is very sensitive to friction, heat, and impact and these properties combined make it one of the most dangerous common explosives to handle. If kept airtight and moisture-free, black powder withstands moderately high temperatures very well. Since the stability of black powder can be affected in varying degrees by absorption of moisture, some of the assembled saluting and impulse charges should be inspected daily to make sure that the pyralin wad seal is airtight. There have been instances in which temperature changes, improper sealing methods, or unknown conditions have permitted black powder to spill from this type of ammunition. When spilled black powder is discovered, it shall be swept up with a fiber brush and recovered in a spark-proof container and the affected area washed thoroughly with water.

Surveillance of Bomb-Type Ammunition. — Bomb-type ammunition is a thin-walled container loaded with a high density charge of explosive. Particular attention must be given to handling and securing the stowage of bomb-type ammunition. Most bomb-type ammunition is subject to mass detonation if exposed to excessive heat or fire. Special precautions shall be taken to ensure that no flammable materials are stowed in bomb-type magazines and that the sprinkler system is capable of completely flooding the magazine in case of fire in or near the magazine.

Removing TNT Exudate.—The lower grades of TNT may exude a dark, oily substance which is highly flammable. If this substance is absorbed by cellulose substances such as sawdust, wood, or rags, it forms an explosive which is similar to low grade dynamite and more sensitive than TNT. Representative units of TNT-loaded munitions shall be examined during the daily magazine inspection and all TNT-loaded warheads shall be lifted from their stowage rings once every three months in order to fully inspect the stowage space for exudate. If exudation is suspected, no attempt shall be made to evaluate the substance aboard ship. The following procedure shall be followed:

1. Obtain a small sample (2cc or half teaspoonful) of the material in question with a wooden spatula or scraper and place in a glass container secured from the medical department. Seal the container securely and pack in a box with sufficient packing to prevent the bottle from being broken. Forward the sample to the Commanding Officer (Code TC), Naval Ordnance Station, Indian Head, Maryland, with a report of the circumstances which should describe the munitions from which the exudate was obtained and include the mark, mod, manufacturer, lot number, loading activity, date of loading, and all other pertinent information. A copy of the report also should be sent to NAVORDSYSCOM.
2. Tag and segregate the suspected ammunition until results of chemical analysis are known. The exudate may be removed by washing with acetone or alcohol but in no case shall soap, washing compound, or any other alkaline substance be used to wash TNT-loaded munitions.
3. The Naval Ordnance Station, Indian Head will report the results of its tests to NAVORDSYSCOM, to the Ships Parts Control Center (SPCC), Mechanicsburg, Pennsylvania, and to the unit afloat that furnished the sample. If results of the tests are positive, instructions for disposition of the ammunition shall be issued by SPCC.

Surveillance of Detonators and Fuzes.—Initiating devices contain lead azide, lead styphnate, tetracene, or DDNP, all of which are very sensitive to friction, heat, and impact. While the initiating explosives are chemically stable, their sensitivity may diminish seriously when they are exposed to temperatures above 110° F for prolonged periods and sometimes when they absorb moisture. Therefore, stowage spaces which are cool and dry shall be provided for these items. Surveillance shall include control of the temperature and moisture in the stowage space and routine daily inspection of the magazines in which fuze type items are stowed; a daily visual security check will suffice for the depth charge detonator boxes on the weather deck.

Surveillance of Pyrotechnic Ammunition.—Surveillance firing of pyrotechnic ammunition is no longer required; however, when it is fired in training of personnel or during fleet exercises, reports of performance of the ammunition shall be made in accordance with the current instructions existing for the item. At least once a year, pyrotechnics in opened or nonmoistureproof containers shall be inspected for corrosion on the cases, swelling of the paper bodies, dents or punctures in the bodies, condition of the primers, missing safety pins, frayed rip cords, and the presence of chemical odors. Pyrotechnics in moistureproof packaging shall be inspected only for condition of the package. All abnormal conditions observed during the inspection shall be reported to SPCC for disposition instructions.

Surveillance of Chemical Ammunition.—The nature of chemical ammunition is such that it requires individual stowage, which in some instances leads to unusual stowage conditions resulting as a compromise between the hazards of the ammunition and the stowage requirements. With regard to surveillance, chemical ammunition falls into three general categories—smoke, toxic gas, and incendiary.

Smoke.—The three types of smoke-producing agents used by the Navy are liquid FS and FM mixtures and White Phosphorus (WP). Containers of liquid FS and FM mixtures shall be inspected daily. Particular attention should be paid to preventing their exposure to direct sunlight or salt water spray. Fumes leaking past the closure plugs of the containers react with moisture in the air to form a corrosive mist that will attack the outside of the containers. Bulk containers should be well covered with acidproof, weatherproof paint. Exposure of the smoke mixtures to high temperatures may cause pressure inside the containers to build up sufficiently to bulge the container. To prevent this from happening, the filling hole plug may be loosened to release the pressure. The plug should be loosened slowly and carefully to permit the pressure to escape without loss of the liquid smoke mixture. The venting should take place apart from other containers. Containers which become contaminated with the mixture should be flushed off with large quantities of fresh water. Since white phosphorus melts at 110° F, every effort should be made to keep the magazine temperature below 100° F. White phosphorus will smoke and burn spontaneously when exposed to air. Any indication of smoke within the magazine shall be investigated immediately and the defective round immersed in water until it can be disposed of safely or dumped at sea. Chemical ammunition disposed of at sea shall be dumped at least 10 miles from shore in water that is at least 1000 fathoms deep.

Incendiaries.—Incendiary munitions consist of bombs and projectiles filled with petroleum and metallic derivatives. They should be stored separately but may be stowed with ammunition containing white phosphorus. Surveillance requirements for incendiary munitions are the same as those containing white phosphorus.

MAINTENANCE AND ASSEMBLY OF AMMUNITION AFLOAT

Ammunition and containers must be kept free from rust and deteriorated paint and lacquer renewed as necessary. The paint on the projectiles bourrelets is never renewed aboard ship because the old paint must be removed before repainting so that the dimensions of the projectile bourrelets are not increased. Some of the authorized maintenance operations for ammunition components prescribed by NAVORDSYSCOM are outlined below.

AUTORIZED MAINTENANCE OPERATIONS

Repainting

It is not intended that forces afloat perform extensive repainting of ammunition but only that required to prevent corrosion. When ammunition is found in a condition that requires extensive overhaul and repainting to prevent further deterioration, it should be turned in to the nearest shore ammunition activity for renovation.

Aerosol dispenser spray paints may be used for minor touch up provided the colors match those shown in Federal Standard Number 595 and the integrity of the existing color coding and stenciled legend is maintained. Types of spray paints that meet the specifications listed in OP 4 may be used. Repainting and restenciling shall not be done inside a ship magazine.

Protecting Unpainted Surfaces

Unpainted surfaces of ammunition shall be protected from rust and corrosion by applying a light film of preservative as prescribed by the OP for the item or other NAVORDSYSCOM directive. Cartridge cases shall be kept free of grease and all ammunition received with a light film of oil or grease shall be wiped clean prior to firing except when the OP or other directive requires a lubricant on the item when fired. Any instance of corrosion or deterioration which may be due to nonapplication of a preservative should be reported to NAVORDSYSCOM along with the circumstances under which it occurred. Repeated removal of rust, verdigris, or other corrosion in lieu of applying a preservative is forbidden since critical characteristics of the item may be altered. Ammunition items which become wet for any reason shall be wiped or dried immediately.

Tightening Lids of Containers

Smokeless powder cans shall be maintained airtight. When it is necessary to tighten lids, only authorized wrenches of spark-proof material shall be used. When containers having tear strip lids are opened and a portion of the ammunition removed, the container shall be tightly closed and resealed with Cloth (ordnance) Tape, pressure adhesive, PPP-T-60, Class 1 or equivalent, to ensure that the container is airtight. This is especially important for pyrotechnics where several containers may have to be opened but only a part of the items expended.

Tightening and Repairing Grommets

Grommets which are stored attached to ammunition must be maintained by the custodian of the ammunition. They may be tightened, adjusted, repaired, or replaced by the ship's force whenever necessary to provide proper protection for the ammunition.

FORBIDDEN MAINTENANCE OPERATIONS

Breakdown

The separation of a complete round or component into its separate parts shall not be permitted aboard ship without specific instructions from NAVORDSYSCOM. When breakdown of an item is authorized, only specially qualified persons shall perform the operation in a safe location.

Removing Filling Hole Covers

Removal of filling hole covers from explosive loaded mines and depth charges to replace gaskets during routine maintenance or for other reasons is hazardous. A little explosive on threads of studs or in cap screws holes could produce a low order detonation when the nuts or cap screws are moved. There is no need to tighten or remove these nuts or cap screws since leakage of a small amount of water through the filling hole has no adverse effect on the explosive filler.

Additional Forbidden Operations

In addition to forbidden operations discussed in the preceding paragraphs, the following maintenance operations also are forbidden aboard ship:

1. Making additions to smokeless powder bags.
2. Removing a base fuze from a loaded projectile or rocket head.
3. Breakdown of a fuze.
4. Removing a nose fuze which would expose main explosives charges.
5. Using unauthorized tools or equipment in handling ammunition.
6. Making alterations to service, training, and dummy drill ammunition unless specific approval is obtained from NAVORDSYSCOM. (Alterations include not only changes in configuration and components, but also changes in appearance such as color coding.) The latter is considered vital to preclude mistaken identity.
7. Assembling torpedo or depth charge impulse charges.
8. Fuzing or defuzing white phosphorus projectiles.
9. Repairing projectiles with loose caps, windshields, or fuzes.
10. Applying "field-fix" modifications to ammunition except as directed by NAVORDSYSCOM.
11. Checking-out explosive electrical circuits except as authorized by NAVORDSYSCOM.
12. Reworking complete assemblies of unserviceable ammunition.

Fuzing and Defuzing

In any authorized operation involving fuzing, defuzing, assembly, disassembly, or cleaning of all types of ammunition, the work shall be accomplished in the most suitable location, taking into account safe removal from other explosives and possible damage to vital installations; the smallest number of rounds practicable shall be involved. Only those persons essential for the work shall be in the vicinity. The ideal situation would be one in which work would be performed on only one round at a time, in a location on deck remote from all magazines, from ready stowages, from other supplies of ammunition or explosives, and from vital installations.

GUN-TYPE AMMUNITION.—High capacity projectiles are issued to ships with a steel nose plug installed and accompanied by a mechanical time fuze and a point detonating fuze which may be assembled into the projectile according to its intended use. The projectiles are fitted with an auxiliary detonating fuze which is permanently installed in the nose and separates the nose fuze from the high explosive filler. The auxiliary detonating fuze is considered sufficient protection against exposing the high explosive filler to permit fuzing and defuzing the projectiles aboard ship. This interchanging of mechanical time fuzes, point detonating fuzes and steel nose plugs pertains only to high capacity projectiles and a fuze or plug shall remain in each projectile at all times except when actually being removed during interchange.

VT FUZES.—Since the auxiliary detonating fuzes associated with VT fuzes are attached to the fuze sleeve (body) and are not installed in the projectile, installing or removing VT fuzes is authorized aboard ship. Ammunition designed for VT fuzes is fitted with a cavity liner which serves as a safety factor for the fuzing operation.

WHITE PHOSPHORUS-LOADED PROJECTILES.—White phosphorus-loaded projectiles do not contain auxiliary detonating fuzes and may be extremely dangerous when defuzed. Under no circumstances shall white phosphorus-loaded projectiles be fuzed or defuzed aboard ship since white phosphorus ignites spontaneously when exposed to air.

ROCKET AND BOMB AMMUNITION.—In most instances aircraft bombs, missile warheads, and rocket heads are issued without fuzes and have suitable plugs in the fuze cavity. Rocket heads which use base fuzes are shipped with the base fuze installed. An allowance of fuzes, issued according to the proposed use of the ammunition, is stowed separate from the ammunition. Fuzing of bombs shall normally be accomplished after the bombs are loaded on the aircraft. Exceptions are: (1) Fuzes which require installation in the assembly area shall be installed at the last practical moment prior to transfer to the rearming area for loading on the aircraft. (2) Fuzes which require installation prior to loading an aircraft due to insufficient clearance for fuze installation after bombs are on racks shall be installed immediately prior to hoisting bomb to rack. Fuzing of rocket ammunition shall be done just prior to placing it in ready service stowage or just before or after loading it on the launcher. In general, fuzing of bomb and rocket ammunition should be done in an area which is as isolated as possible from other ammunition yet be as close to the launcher as possible. The space must be large enough to accommodate the prescribed tools, equipment, and personnel to ensure a continuous or adequate flow of ammunition from the magazines to the launchers or aircraft. In the case of aircraft bombs and large rockets and missiles, the most likely spaces are at hoist interruptions between the magazines and the launcher or aircraft. During fuzing operations, the least number of rounds practicable should be exposed at a time. Detailed instructions for fuzing individual marks and mods of rocket and bomb ammunition are contained in ordnance pamphlets written expressly for the particular ammunition. Personnel assembling rocket ammunition shall wear long trousers and long sleeved shirts with the sleeves and collars buttoned. All work shall be performed from the side of the rocket insofar as practicable. Rocket heads shall be inspected to ensure that the base fuze is properly in place before assembling motors to them. Rocket motors shall be inspected to ensure that the rear closure is properly in place. Care shall be taken to prevent damage to rocket, bomb, and missile fin assemblies during assembly operations. Fuzed ammunition shall not be allowed to accumulate at the fuzing station and should be moved to the launcher immediately upon being assembled. All designated safety devices shall be in place before the ammunition is moved to the launcher.

SALUTING CHARGES.—Ships designated as saluting ships are issued an allowance of assembled saluting charges. Ships not designated as saluting ships, but which may be required to render salutes, and those designated as saluting ships, but not having saluting batteries, are issued 3''/50, 5''/38, or 5''/54 (slow fire) saluting charges as applicable for the batteries on board. Saluting charges shall not be assembled aboard ship. Before being used, all saluting cartridges shall be examined to make sure primers and plugs or wads are properly seated.

MAXIMUM TIME AMMUNITION MAY REMAIN AFLOAT

NAVORDSYSCOM considers that the normal return of ammunition during regularly scheduled major yard overhauls will prevent the storage of unserviceable or dangerous ammunition afloat. The instructions issued to ammunition activities are the results of quality evaluations, and an ample safety factor in assigned serviceable life is allowed to provide for stowage periods in excess of normal. The responsibility for issuing serviceable ammunition to the fleet rests with the commanding officers of ammunition activities. NAVORDSYSCOM requires that commanding officers of ships stow certain ammunition afloat only for perscribed periods of time.

Gun-Type Ammunition

All smokeless powder charges and cartridges which have been on board ship for five years after assembly or reassembly shall be returned to an ammunition activity for examination, test, and renovation during the ship's next regular major overhaul availability. In no case shall smokeless powder charges remain aboard ship longer than seven years after assembly or reassembly. All smokeless powder charges and cartridges which have been on board ship three years since renovation at an ammunition activity shall be returned to an ammunition activity for examination, test, and renovation at the ship's next major overhaul availability. In no case shall such charges remain aboard ship longer than four years without renovation.

Rocket-Type Ammunition

Rocket motors shall be turned in to an ammunition activity for renovation five years after original assembly and every three years thereafter. The motors shall be turned in at the first opportunity after the times specified. Rocket heads assembled with base detonating fuzes shall be turned in for renovation three years after loading or reassembly or two years after the last renovation inspection. Rocket heads assembled with nose fuzes or auxiliary detonating fuzes shall be turned in five years after loading or three years after renovation inspection. Rocket heads with primacord ignition trains shall be turned in five years after loading or two years after renovation inspection. The shorter age limit is applicable for heads packaged with motors. All rocket fuzes and unserviceable inert components shall be turned in at the same time as motors and heads.

Guided Missiles

The shelf-life of guided missile warheads is quite long and no turn-in date is presently in effect. Should any indication of abnormal deterioration be noted (such as exudate or excessive corrosion), NAVORDSYSCOM should be notified promptly. The shelf-life or other missile explosive components is checked periodically by NAVORDSYSCOM to ensure weapon reliability. The shelf-life of rocket motors varies from three to more than ten years. All rocket motors are stamped with a date after which the motor shall not be fired. When it appears that more motors are aboard than will be expended prior to their expiration date, instruction for disposition should be requested from NAVORDSYSCOM. Rocket motors with expired dates should be returned to a depot at the first opportunity.

ARRANGING FOR INSPECTION

If desirable, the commanding officer of the ship concerned will arrange with the commanding officer of the ammunition activity to inspect the ammunition to be turned in. This inspection is for the determination of the ammunition's serviceability and depends on the ammunition activity's ability to perform such inspection. When the work load of the ammunition activity precludes this inspection, the ammunition will be off-loaded without inspection and considered unserviceable until determined to be otherwise. This applies only when ships have interim availability at naval shipyards and not when it is requested to off-load entire allowances. When an inspection is practicable, representatives of the ship's commanding officer shall be present at the place of off-loading to observe and assist in the inspection. They shall inform the ammunition activity of the history of the ammunition and of any unusual conditions to which it was subjected. All records concerning the ammunition shall be made available to the ammunition activity. In cases where ammunition is packaged in permanently sealed watertight and airtight containers, only the container will be inspected and the serviceability of the ammunition determined from the ammunition's history and record.

IDENTIFICATION AND SEGREGATION

The commanding officer of the ship shall have the ammunition segregated by types and, where practical, by lots. He shall ensure that all identification markings are legible or that the ammunition is tagged with complete identifying information. Unserviceable ammunition, suspected ammunition, ammunition in partially filled containers, and ammunition which has been in ready-service stowage shall be conspicuously marked or tagged to indicate its condition. All ammunition must be packaged and protected in accordance with existing instructions. Grommets for ammunition stowed aboard ship without grommets, such as major caliber projectiles, shall be requested from the ammunition activity prior to off-loading. Ammunition which has been removed from containers for assembly into belts or linking devices or for designed stowage shall be placed in its original container or in a proper container whose markings match the markings on the ammunition. When this cannot be done, the ship's commanding officer shall be responsible for ensuring that the ammunition is segregated, securely packed, and conspicuously tagged to indicate this condition. A complete inventory of the ammunition to be off-loaded shall be furnished to the commanding officer of the ammunition activity.

RENOVATION OF AMMUNITION

The ammunition activity normally is equipped with facilities and specially trained personnel to determine the serviceability of fleet returned ammunition and to renovate unserveceable ammunition so that it will be suitable for a normal afloat stowage period. If work load permits and NAVORDSYSCOM so directs, the ammunition shall be renovated for possible return to the same ship from which it was off-loaded.

Necessity For Renovation

Certain integral components of all ammunition are subject to deterioration and must be repaired or replaced through breakdown and renovation. Since the facilities and specially trained personnel required for these operations are not provided to forces afloat, renovation operations are authorized only at shore based ammunition activities and certain Mobile Ammunition Evaluation Reconditioning Units (MAERU) under the cognizance of NAVORDSYSCOM.

SURVEILLANCE AFTER A CATASTROPHIC EXPLOSION

During 1969 U.S. Navy experienced four in-bore catastrophic explosions and an allied ship using U.S. Navy ammunition experienced one. The ensuing investigation concluded:

1. Projectile base hole closure defects were a contributing cause; lack of a good copper-lead seal being the most important single factor. Other defects could exist, however; if the gas check seal (GCS) was good, the probability of an in-bore detonation was low. Also, a gap between the base fuze and the explosive filler, alone or in combination with low density of the explosive filler, could contribute to a phenomenon causing the explosive filler to ignite.
2. Fuze defects were not a contributing cause of the in-bore detonations, however, they are probably the primary cause of close-aboard prematures and early-bursts.
3. Explosive filler cracks and projectile body cracks, though a potential cause for in-bore detonations, did not contribute to the five incidents studied, as far as can be determined, (fig. 12-2 illustrates projectiles components). In summary, the conclusions of each incident are expressed as follows:

ACCIDENT	CAUSE
29 May 69 USS LOWRY (5"/38)	Defective or missing gas check seal
9 July 69 USS BOSTON (5"/38) 2 Oct 69 USS BOSTON (5"/38)	Critical combinations of gap/density factors in the explosive filler.
22 July 69 HMAS BRISBANE (5"/54) 7 Nov 69 USS HOEL (5"/54)	Possibly compounded by defective or missing gas check seal.

Complete details of the investigations are contained in NAVORD Report 10009.

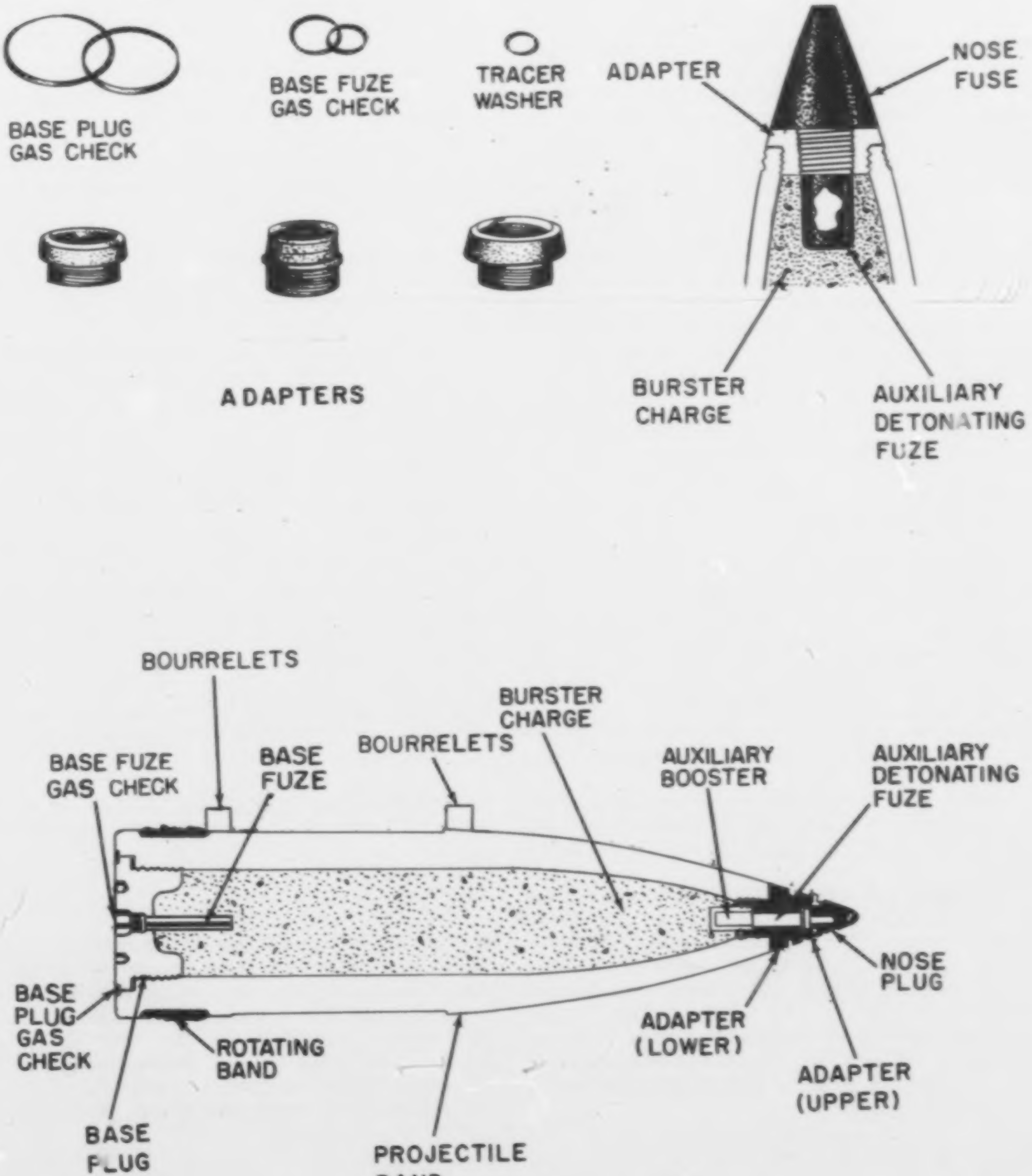
Corrective Actions

As a result of the investigation, several pertinent facts were disclosed. Most important was the apparent lack of understanding regarding the inspection of ammunition. Few gunnery personnel readily understood the principle of the gas checking system in the base of projectiles. Shipboard personnel were apparently not familiar with the gun ammunition lot system. Also, reported malfunction data was frequently incomplete, incorrect, or not in proper descriptive terminology. All parties involved contributed to this undesirable situation and, therefore, no one group was significantly to blame. However, it was apparent that increased understanding was required.

Ammunition, in any form is dangerous unless it is properly tended. Any deviation from authorized procedures can lead to problems. Minor unauthorized acts can establish a train of events which can eventually cause a magazine to blow. Therefore, it is imperative that ordnance personnel follow standard operating procedures exactly; if any doubt exists—contact the nearest ammunition facility for guidance.

Shipboard Examinations

NAVORD has directed the mandatory inspection of 5, 6, and 8-inch high explosive loaded projectiles for a good gas check seal (GCS) prior to issue by NAVORD shore activities or overseas ammunition issuing activity. This GCS inspection by experienced ammunition personnel included SIGHTING (1) that the GCS was not missing, (2) that the GCS was symmetrical and properly seated, (3) that it was not cracked, cut or torn, and (4) that the BDF (Base Detonating Fuze) or BFHP (Base Fuze Hole Plug) was flush or slightly below the projectile base. Issuing activities ashore after inspection certified a good GCS by applying a suffix, either A or


BASE PLUG
GAS CHECK
BASE FUZE
GAS CHECK
TRACER
WASHER
ADAPTERS
ADAPTER
NOSE
FUSE
BURSTER
CHARGE
AUXILIARY
DETONATING
FUZE
BOURRELETS
BURSTER
CHARGE
BOURRELETS
BASE FUZE
GAS CHECK
BASE
FUZE
AUXILIARY
BOOSTER
AUXILIARY
DETONATING
FUZE
NOSE
PLUG
BASE
PLUG
GAS
CHECK
ROTATING
BAND
ADAPTER
(LOWER)
ADAPTER
(UPPER)
BASE
PLUG
PROJECTILE
BAND

84.296(53C)

Figure 12-2.—Typical projectile components.

B in accordance with OD 17190 as appropriate, on the projectile and the data card.

As a further safeguard against inadvertent damage during subsequent handling and the possibility of sabotage, the firing ship should, prior to use, examine each 5, 6, and 8-inch high explosive loaded projectile for a proper gas check seal. Also, when feasible, ordnance personnel should examine ammunition to see that waterproof protecting caps are properly installed, nose fuzes are properly seated and not loose; upper nose caps of fuzes are intact, and that complete rounds can be identified by lot identification number. It is imperative that no complete round be used which cannot positively be identified by its complete lot identification marking and suffixed for screening action in accordance with OD 17190. This system of identification is simple but it requires study to understand and must be followed to be effective. Plans are underway to simplify the management of the system, however, no significant changes to this system are expected.

NOTICES OF AMMUNITION RECLASSIFICATION

In cases where it has been determined that an ammunition item may endanger life or property, rapid promulgation of the information is accomplished by a message of Notice of Ammunition Reclassification (NAR). All NARs are sent to all activities listed in an Address Indicator Group (AIG) promulgated by SPCC under the direction of CNO. NARs are numbered consecutively starting with each calendar year. (Example: NAR 1-71.)

NARs will be incorporated into OD 17190 (Ammunition, Unserviceable, Suspended and Limited Use) as changes to that publication are made.

NAVORD OD 17190 is published under the joint direction of NAVAIRSYSCOM and NAVORDSYSCOM. The publication promulgates information pertaining to the degree of serviceability of ammunition and components thereof which are used by the Navy, Marine Corps, and Coast Guard. It contains a listing of items, usually by lot number, which are NOT suitable for unrestricted use in the manner for which they are designed.

Status and Condition Code

For convenience a status and condition code consisting of a single alpha character, one for each code, appears in OD 17190 for all entries. A breakdown of the coding system follows:

UNSERVICEABLE STATUS CODE (U).—Ammunition not suitable for issue or use.

UNSERVICEABLE CONDITION CODES.—(E) Limited Restoration, (F) Repairable, (H) Condemned.

LIMITED USE STATUS CODE (L).—Ammunition suitable for or restricted from a specific use.

LIMITED USE CONDITION CODES.—(B) Serviceable, issuable with qualifications. (N) Limited use, for combat use only.

RELEASED STATUS CODE (R).—Ammunition which has been tested and evaluated and determined to be suitable for a return to serviceable status.

RELEASED CONDITION CODE (A).—This appears only with released serviceable items.

SUSPENDED STATUS CODE (S).—Ammunition suspended from issue and use, other than combat use, pending its reclassification. Combat use, and issue for combat use only, is authorized when nonrestricted ammunition is not available locally. In certain very hazardous situations it is possible that an item may be considered unsuitable for even combat emergency use. Such items will be identified as "Suspended, from all use including combat."

SUSPENDED CONDITION CODE (J).—The true condition of the ammunition is not known.

GUN AMMUNITION LOT NUMBERS

The quantities of ammunition now being handled have necessitated a more exact and readily usable identification system to simplify recognition and reports both afloat and ashore. Such a system has been established in the form of a gun ammunition assembly lot number system. The gun ammunition assembly lot number is composed of a prefix, a numerical group, and a suffix.

Prefix

The prefix indicates the caliber and type of ammunition and consist of either two letters, for new ammunition assemblies; or three letters for renovated ammunition.

Numerical Group

The numerical group indicates the actual lot number for the particular year shown by the suffix. Numbers shall be assigned in sequence from 1 to 9999 beginning with lot 1 for the first lot of the particular type of ammunition started in each calendar year.

Suffix

The suffix shall consist of a letter or letters indicating the activity manufacturing or renovating the ammunition, and a two-figure number indicating the year of assembly.

An example of a lot number system is BER-5-GU-59. This is the fifth lot of a 5''/38 AAC projectile assembled at ammunition activity Guam in 1959. The letter ''R'' in three letter prefix designate a renovated ammunition lot.

An alpha suffix following a lot number is a relatively new system in ammunition identification. Example: BER-5-GU-59A. The suffix indicates some type of screening or other work not requiring a rework lot number. Example; inspection for a good gas check seal. The suffix does affect the status of a lot from a serviceability standpoint. For example: BER-5-GU-59 might be listed in OD 17190 as unserviceable, this does not affect lot BER-5-GU-59A which is a serviceable lot. Since this letter suffix system is relatively new, it must be carefully noted especially when NAR messages are promulgated.

Naval Ammunition Logistic Code (NALC)

The NALC is a four-digit alpha/numeric code assigned to nonnuclear ammunition components and related material used by the Navy and Marine Corps. These codes provide overseas bases, fleet units, and shore establishments with standard ammunition logistic code numbers which may be used for recording, reporting, and requisitioning. Complete information on logistics codes is found in OD 16135, Navy Ammunition Logistics Code.

GUN AMMUNITION COMPONENTS

Ammunition components used in the assembly of certain gun ammunition are illustrated in figures 12-2 and 12-3. The components shown are non-explosive items used in the assembly of gun ammunition which help prevent accidental detonation when handling, loading, and firing gun type ammunition.

The following items are components used in the assembly of projectile ammunition (figure 12-2).

Gas Checks

Gas checks are constructed of a copper ring with a lead core. These are assembled under pressure around the base fuze, base plug and/or base fuze hole plug, to prevent the gases from the propellent from entering the projectile.

Tracer Washers

Lead washers are placed between the shoulder on the tracer body and the corresponding seating surface in the base plug of the projectile. These washers prevent gases from affecting the base fuze or explosive filler.

Adapters

Adapters are used in conjunction with AAC and AC rounds, into which the auxiliary detonator and nose fuze are assembled. The following items are components used in assembly of cartridge cases, (figure 12-3).

Plastic and Cork Plugs

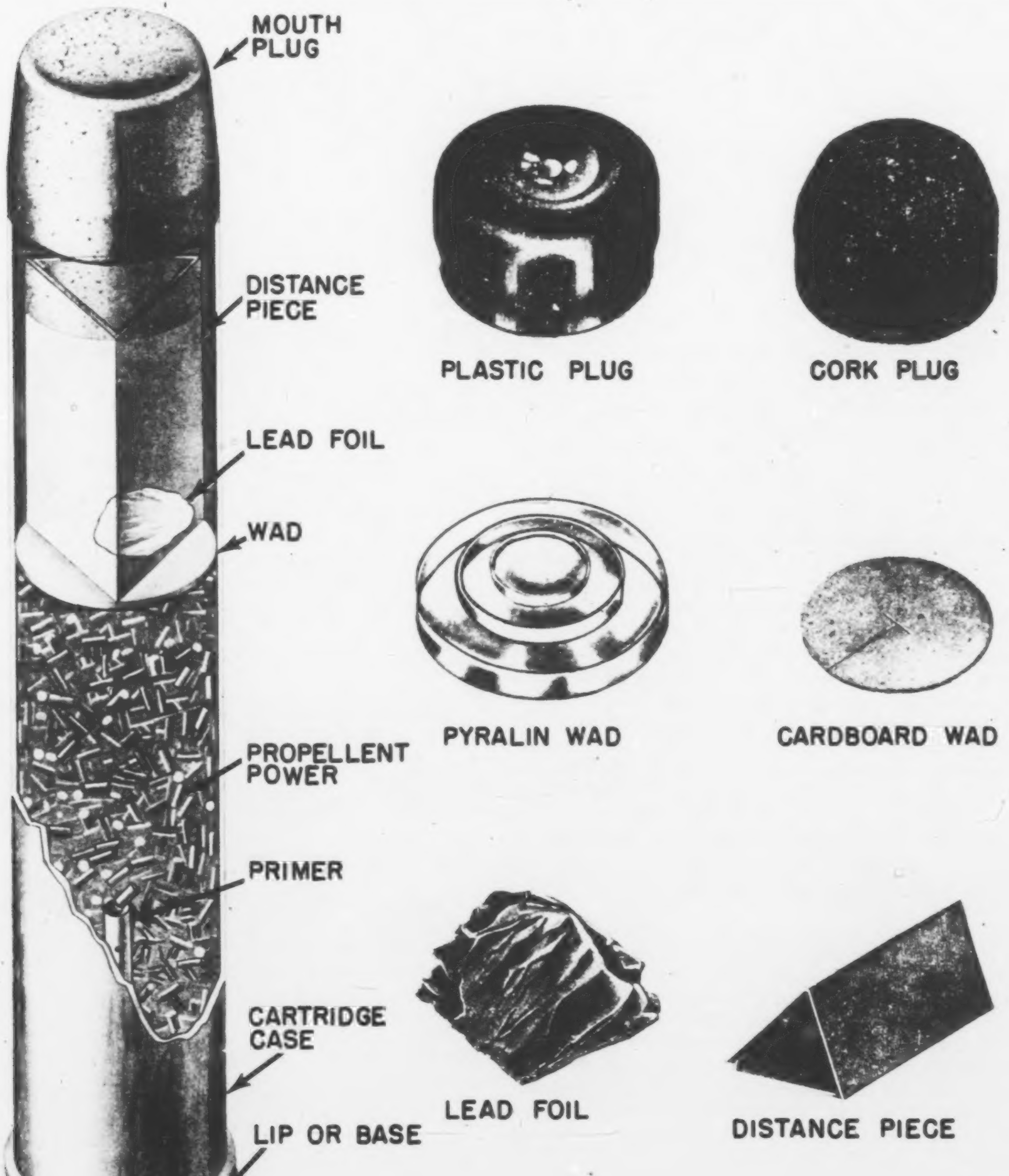
Plugs are used in the mouth of cartridge cases in the assembly of propellent charges. They seal the end of the cartridge case and act as a buffer when the case is rammed into the gun against the projectile.

Pyralin Wad

This wad is made of combustible material and is used to retain the black powder in the assembly of special charges; such as saluting, torpedo impulse, and depth charge projector.

Cardboard Wad

This is a wad used to help retain the smokeless powder in a propellent charge.


MOUTH PLUG
DISTANCE PIECE
LEAD FOIL
WAD
PROPELLENT POWER
PRIMER
CARTRIDGE CASE
LIP OR BASE
PLASTIC PLUG
CORK PLUG
PYRALIN WAD
CARDBOARD WAD
LEAD FOIL
DISTANCE PIECE

84.9(53C)
Figure 12-3.—Typical cartridge case components.

Lead Foil

A wad of lead foil is placed inside the distance piece of a propellent charge to prevent the deposit of copper from the projectile rotating bands in the base of the gun. It is also used with bag charge ammunition for the same purpose. The lead acts as a lubricant, on which copper deposits will not adhere.

Distance Piece

This is a rectangular piece of cardboard folded into a triangular shape and used in propellent charges to act as a support between the wad and the mouth plug.

MALFUNCTION (MALF) REPORTING

MALF's are reported in accordance with NAVORDINST 8025.1A. However, two areas of reported data require improvement to assist NAVORD to expeditiously initiate investigations:

1. Complete and proper identification of items involved, including use of proper terminology.
2. Reports of the sequence of events including accurate distance estimates when premature or early bursts are reported.

Two established guidelines may be used to assist ordnance personnel in reporting facts; (1) fuzes, to date have not been identified as a culprit in causing in-bore detonation; (2) close-aboard, or out-of-bore prematures are usually caused by fuze malfunction.

To assist ships in identifying suspect items, it is considered good gunnery practice to establish a local system of stowing ammunition for immediate use prior to exercises or in preparation for action so that if an incident does occur, a reasonable opportunity exists to later identify the item which malfunctions. Pre-action stowage plans for ready service ammunition is recommended. Whenever an ammunition item cannot be completely identified by its assigned lot identification number, it should be set aside and turned into the nearest ordnance activity with a shipping tag explaining the problem.

ROCKETS AND MISSILES

This section is intended to provide an overall view of Navy rockets and missiles associated with the GMG rating. At this writing there are three ordnance systems which use rockets and/or missiles as part of the system.

ASROC

The ASROC weapon (antisubmarine rocket) is a surface-ship launched rocket, carrying a nuclear depth charge or a homing torpedo. It is used against deep diving, fast submarines. The ASROC weapon is launched from rocket launcher Mk 112.

Sparrow

The Sparrow missile is a surface-ship launched weapon used against air and surface targets. It is used with the Basic Point Defense Missile System (BPDMS) which was developed to improve the self defense capability of ships presently without missile defenses. The Sparrow missile is launched from guided missile launcher, Mk 128.

Zuni Rocket

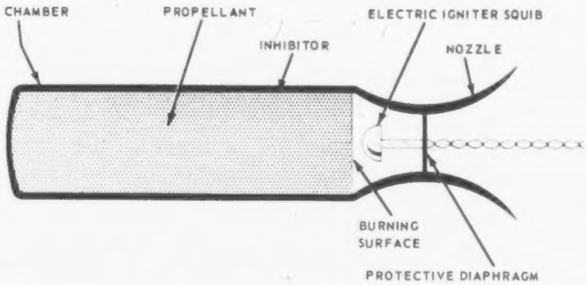
The Zuni rocket is a surface-ship launched weapon used with the CHAFFROC decoy system. The CHAFFROC system was designed to confuse enemy radar missile guidance system by placing single or multiple decoy targets in the sky, utilizing a chaff-filled rocket head attached to a standard Zuni rocket motor. The rocket head is made up of aluminum foil called "chaff." The Zuni rocket is launched from a standard aircraft launching pod supported by a trainable stand.

ASROC, Sparrow, and Zuni weapons all use a solid propellant grain for their rocket fuel.

SOLID-FUEL ROCKET MOTORS

A solid rocket unit consists of the propellant, combustion chamber, igniter, and exhaust nozzle (fig. 12-4).

The combustion chamber of a solid rocket serves two purposes. First, it acts as a storage place for the propellant. Second, it serves as a chamber in which burning takes place. Depending on the grain configuration used, this chamber may also contain a device for holding the grain in the desired position, a trap to prevent flying particles of propellant from clogging the throat section, and resonance rods to absorb vibrations set up in the chamber.



144.25
Figure 12-4.—Components of a solid rocket motor, with end-burning grain.

The igniter consists of a small charge of black powder, or some other material that can be easily ignited by either a spark discharge or a hot wire. As it burns, the igniter produces a temperature high enough to ignite the main propellant charge.

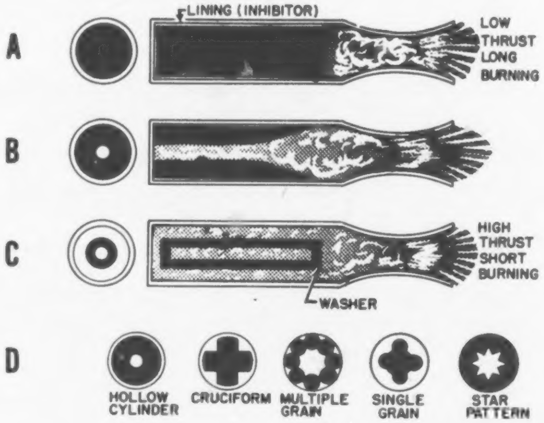
The exhaust nozzle serves the same purpose as in any other jet-propulsion system. It must be of heavy construction and/or heat-resistant materials, because of the high temperatures of the exhaust jet.

Operation of a solid rocket is simple. To start the combustion process, some form of electrically detonated squib is ordinarily used to ignite a smokeless or black powder charge. Upon igniting, the powder charge provides sufficient heat and the pressure to raise the exposed surface of the propellant grain to a point where combustion will take place.

Types of Solid Propellant Charges

Solid propellant charges are of two basic types: restricted burning or unrestricted burning. A restricted-burning charge has some of its exposed surfaces covered with an inhibitor (fig. 12-4). This makes it possible to control the burning rate by confining the burning area to the desired surface or surfaces. The use of inhibitors lengthens the burning time of the charge, and helps to control the combustion-chamber pressure. A burning cigarette can be considered as a model of an inhibited rocket grain, with the paper representing the inhibitor.

A restricted-burning charge is usually a solid cylinder which completely fills the combustion chamber and burns only on the end (fig. 12-5). The thrust is proportional to the cross section area of the charge, and burning time is proportional to length. The restricted burning charge provides relatively low thrust and long burning time. Uses of this type of charge include JATO (jet-assisted takeoff) units, barrage rockets, and sustaining rockets for guided missiles.



12.26
Figure 12-5.—Solid propellant grains: A. Restricted burning; B. Restricted bored; C. Unrestricted burning; D. Grain patterns.

A modification of the restricted burning charge is the bored restricted charge (fig. 12-5B). The main difference is that the longitudinal hole in the charge provides somewhat more burning surface and thus a higher thrust and shorter burning time.

Unrestricted-burning charges are permitted to burn on all surfaces at once. The unrestricted grain delivers a relatively large thrust for a short time. An unrestricted burning charge is usually hollow, and burns on both the outside and inside surfaces (fig. 12-5C). Thrust is again proportional to the burning area. Since the inside area increases while the outside area decreases during burning, it is possible to maintain a nearly constant burning area. The burning time of hollow grains depends on the web thickness—the distance between the inside and outside surfaces. This type of charge is commonly used in booster rockets.

It should be clearly understood that in both the restricted and unrestricted burning charges, the burning rate is controlled—there is no explosion. Controlling the burning rate of a solid propellant has always presented a problem to rocket designers. You will recall that one of the properties of an ideal solid propellant would be that it ignite and burn evenly. The burning rate may be controlled in several ways. One is by means of inhibitors. An inhibitor is any substance which interferes with or retards combustion. The lining and the washer shown in figure 12-5 are examples of inhibitors. Another way that burning is controlled is by use of various grain shapes. Examples are the shapes shown in the lower part of figure 12-5D. Resonant burning or "chugging" may be offset by the use of resonance rods. These metal or plastic rods are sometimes included in the combustion chamber to break up regular fluctuations in the burning rate and their accompanying pressure variations. The purpose of the various designs is to maintain a constant burning area while the surface of the grain is being consumed.

Until recently, a serious disadvantage of the solid propellant had to do with the problem of dissipating the extreme heat of combustion.

One way this has been overcome is by use of the internal burning grain. Since the burning process actually takes place within the grain, the outer portion of the grain provides a shield between the intense heat and the combustion chamber wall until the grain is almost completely consumed.

Burning Rate of Solid Propellant Grains

The burning rate of a solid propellant is the rate at which the grain is consumed; it is a measure of linear distance burned, in inches per second, in a direction perpendicular to a burning surface.

As stated earlier, thrust depends on mass rate of flow and the change in velocity of the working fluid. For large thrust, a large burning area is necessary in order to yield a large mass flow. A smaller burning area produces less mass flow and less thrust. Therefore, by varying the geometrical shape and arrangement of the charge, the thrust developed by a given amount of propellant in a given combustion chamber can be greatly influenced.

The burning characteristics of a solid propellant depend on its chemical composition, initial temperature, combustion-chamber temperature and pressure, gas velocity adjacent to the burning surface, and size and shape of the grain. One propellant grain may burn in such a way that the burning area remains constant, producing constant thrust. This type of burning is known as NEUTRAL BURNING. End-burning propellant grains are of this type. Another important neutral-grain design is the uninhibited, internal-external burning cylinder (fig. 12-5C), which is used where a short-duration thrust is needed, as in bazooka type rockets. The propellant burns so rapidly that heating of the chamber walls is not excessive.

Another type of grain increases its burning area as burning progresses. In this case, PROGRESSIVE BURNING is taking place. Thrust increases as the burning area increases. Still another grain may show a constantly decreasing burning area as burning progresses. This is called DEGRESSIVE BURNING. It results in a decreasing thrust. Various star-shaped perforations (fig. 12-5D) can be used to give neutral or degressive burning characteristics, but design changes can make them progressive burning.

Propellant grains are often formed by extrusion; these, of course, are installed in their cases after forming. But certain types of composite propellants, bonded by elastomeric fuels, can be cast directly in the rocket chamber, where the binder cures to a rubber and supports the grain by adhesion to the chamber walls. This is called case-bonding.

It permits full use of the chamber space. Most high-performance rockets are made by this technique.

Description of Solid Propellants

One limitation of solid propellants is sensitivity to temperature. The initial temperature of a grain noticeably affects its performance. A given grain will produce more thrust on a hot day than it will on a cold day. The percentage change in thrust per degree Fahrenheit temperature change is referred to as the temperature sensitivity of the propellant. A grain designed to produce 1000 pounds of thrust at 80° F may deliver only 600 pounds of thrust at 30° F. The initial temperature also affects the burning rate. Because of these characteristics, solid propellants must be stored in areas of controlled temperature until they are used.

Temperature also affects the physical state of solid-propellant grains. At extremely low temperatures, some grains become brittle and are subject to cracking. Cracks increase the burning area and burning rate and therefore increase the combustion-chamber pressure. If this pressure exceeds that for which the chamber was designed, the chamber may explode. A propellant exposed to high temperature before firing may lose its shape, and become soft and weak. This, too, results in unsatisfactory performance. The temperature range for most solid propellants is from about 25° F and 120° F. Correct storage temperature retards the decomposition of propellants that contain nitrocellulose (almost all of them do), which inevitably deteriorate with time, in spite of the addition of stabilizers.

Pressure limits play an important part in solid propellant performance. Below a certain chamber pressure, combustion becomes highly unstable. Some propellants will not sustain combustion at atmospheric pressure. Ordinarily, chamber pressure for solid propellants must be relatively high. For a given propellant composition and burning area, the chamber pressure is determined by the area of the exhaust nozzle throat. If the throat area is too large, for example, proper chamber pressure cannot be maintained.

Decomposition and hygroscopic tendencies are other weaknesses of solid propellants, but both can be minimized by the use of certain additives. Change in the moisture content changes the gaseous energy output of the propellant with unpredictable results.

Some of the more common propellants are discussed below. The chemical formulas of some of them are given to show the carbon and/or hydrogen content, and the oxygen content of the oxidizers.

One of the first solid propellants used was BLACK POWDER. Its approximate composition is:

Potassium nitrate (KNO_3)	61.6%
Charcoal (C)	23.0%
Sulphur (S)	15.4%

Both charcoal and sulphur react readily with oxygen. Potassium nitrate, as shown by its formula, contains large quantities of oxygen. The three ingredients are thoroughly mixed, using some substance such as glue or oil as a BINDER.

When heat is applied to black powder, the potassium nitrate gives up oxygen. The oxygen reacts with the sulphur and carbon, producing intense heat and large volumes of carbon dioxide and sulphur dioxide. These two gases make up the major part of the exhaust jet. The heat produced by the reaction gives high velocity to the exhaust gases. Black powder has a specific impulse of about 65 lb-sec/lb. One of its drawbacks is that it is quite sensitive to storage temperatures, and tends to crack. Its exhaust velocity ranges from 1500 to 2,500 feet per second. It is now used primarily for signal rockets, and as an igniter for other solid-propellant grains.

BALLISTITE is a double-base propellant; it contains two propellant bases, NITROCELLULOSE and NITROGLYCERINE. It also contains small amounts of additives, each performing a specific function. A STABILIZER absorbs the gaseous products of slow decomposition, and reduces the tendency to absorb moisture during storage. A PLASTICIZER serves as a binding agent. An OPACIFIER is added to absorb the heat of reaction and prevent rapid thermal decomposition of the unburned part of the grain. A FLASH DEPRESSOR cools the exhaust gases before they escape to the atmosphere, thus preventing a burning-tail effect. A typical ballistite composition is

Nitrocellulose $C_{24}H_{40}O_{20}(NO_3)$	51.38%	(propellant)
Nitroglycerine $C_3H_5(NO_3)_3$	43.38%	(propellant)
Diethylphthalate	3.09%	(plasticizer)
Potassium nitrate	1.45%	(flash depressor)
Diphenylamine	0.07%	(stabilizer)
Nigrosine dye	0.10%	(opacifier)

Ballistite has a specific impulse of about 210 lb-sec/lb. Its exhaust is relatively smokeless. Storage temperatures between 40% F and 120° F are necessary to prevent rapid decomposition. The ingredients of ballistite are subject to detonation, and are toxic when they come in contact with the skin. The manufacturing process is difficult and dangerous.

Galcit consists of about 25% asphalt-oil mixture, which serves as both fuel and binder, and 75% potassium perchlorate ($KClO_4$), which serves as an oxidizer. In its finished form, Galcit resembles stiff paving tar. Recommended temperature limits for firing are 40° F to 100° F. The specific impulse of galcit is about 186 lb-sec/lb. It is quite stable to temperature; storage temperature limits are minus 9° F to 120° F. Galcit is relatively easy to manufacture. It is nonhygroscopic — that is, it does not absorb moisture. Its major disadvantage is that its exhaust develops dense clouds of white smoke. It is only about one-fifth as sensitive to temperature changes as ballistite, but it becomes brittle at low temperatures and soft at high temperatures.

NDRC propellants were developed through research sponsored by the National Defense Research Committee. A typical composition consists of about equal parts of ammonium picrate and sodium nitrate (46.5% each), and 7% resin binder (usually urea formaldehyde). This propellant has good thermal stability. It is hygroscopic, and must therefore be stored in sealed containers. Heavy smoke develops in the exhaust gases.

Solid propellant rockets are particularly adaptable to shipboard use. They are easily stored and ready for immediate use. So great have been the improvements in solid propellants in the past few years that they are now used in such long-range missiles as the Navy's Polaris and the Air Force's Minuteman.

ROCKET MOTOR PRECAUTIONS

Rocket motors contain propellant grains which are easily ignited. Keep motors grounded at all times and away from electromagnetic radiation, stray voltages, and static electricity. The propellant grains must not be exposed to extremely high temperatures. Whenever possible, maximum continuous magazine storage temperature should not exceed 90° Fahrenheit. Since shipboard surveillance tests are not authorized, the oldest propellant lots are used first to maintain maximum safety.

ROCKET AND MISSILE DESIGNATIONS

The Department of Defense has an established uniform system for designating, redesignating, and naming military rockets and guided missiles. The system covers all current and newly designed military rockets and guided missiles with a combat or combat related mission. The explanation of system which makes up the alphabetical and numerical structure of the designation of rockets and missiles and the popular name of the weapons and some of the terms used to identify them follows.

1. Type Designation. The minimum combination of letters and numbers required to adequately identify a rocket or guided missile (as explained in paragraph under "Elements of Nomenclature").

2. Vehicle. A rocket or guided missile, including either one used as a probe.

3. Rocket. A self-propelled vehicle without installed or remote control guidance mechanisms and whose trajectory or flight path cannot be altered after launch. Rocket systems designated for line-of-sight fire are not included.

4. Guided Missile. An unmanned, self-propelled vehicle designed to move in a trajectory or flight path all or partially above the earth's surface and whose trajectory or course, while the vehicle is in motion, is capable of being controlled remotely or by homing systems or by inertial and/or programmed guidance from within. This term does not include space vehicles, space boosters, or naval torpedoes, but it does include target and reconnaissance drones.

Elements of Nomenclature

Standard nomenclature for a guided missile or rocket consists of a noun name plus the type designation followed by a popular name; for example Rocket RUR-5A-1 ASROC. Each type designation consists of a combination of significant letters and numbers described in the following paragraphs in order of listing.

The first letter R denotes the environment from which the vehicle is launched, (R = Launched from a surface vessel such as a ship, barge, etc).

The second letter U designates the primary mission of the vehicle, (U = Vehicles designed to destroy enemy submarines or other underwater targets or to detonate underwater).

The third letter R is the vehicle type symbol designating the kind of vehicle, (R = Rocket).

The first number 5 is the design number designating each vehicle type with the same basic design. Design numbers are assigned consecutively, beginning with "1" for each type vehicle, example 5 is an ASROC and 44 is a SUBROC.

The letter A is a series symbol used to denote the basic configuration and follow-on modifications to the vehicle that result in significant differences affecting the relationship of the vehicle to the nonexpendable portions of the related system. Series symbol letters are assigned consecutively, beginning with 1.

The number 1, the version number, denotes configuration changes that will affect performance or tactics but have no effect on the nonexpendable portions of the related system components and no significant effect on logistic support.

ROCKET MOTOR IDENTIFICATION

Rocket motors are identified by a Mk and Mod number, a serial number, an ammunition and propellant grain lot number, and a FSN number. The ASROC weapons use a 11.65" rocket motor Mk 1 or Mk 37. The temperature range in which the rocket motor may be used is also included in its identification information.

ROCKET MOTOR INSPECTION

All solid propellant rocket motors must be inspected for the following points.

1. Rocket motors shall be inspected for physical damage upon receipt aboard ship. If the unit is damaged or suspected of being damaged, it shall be returned for disposal in accordance with NAVORDSYSCOM instructions.
2. Upon receipt aboard ship of any rocket motor with a mechanical arming and safety mechanism, the ignition system arming mechanism shall be inspected immediately to ensure that it is set on SAFE. If it is not, qualified personnel shall consult applicable instructions for the unit to determine the correct positioning of the arming and safety mechanism and immediately set the mechanism to the prescribed position. The receipt of the rocket motor with this mechanism incorrectly set shall be immediately reported to NAVORDSYSCOM. Handle motors with extreme care. An impact may crack the propellant grain which can cause an explosion upon firing.

Each rocket motor has an expiration date stencilled on it and shall not be fired after the expiration date unless otherwise authorized.

ASROC INSPECTION AND TESTING

There are several different types of guided missiles for different applications just as there are different types of gun projectiles. Some of the guided missiles now used in the fleet are adapted for conventional as well as nuclear warfare. One of these weapons which can use a nuclear component is the ASROC missile used in ASW systems.

In nuclear weapons, safety is of prime importance in three main classes of components for each weapon. One class is the conventional high explosive and propelling charge. A second class in the combination of mechanical and electrical devices that provide for handling, arming, and firing. The third and final class is the nuclear material.

Conventional Explosives

High explosives, propellants, and detonators are integral parts in the construction of nuclear weapons. Due to the presence of these explosive hazards, the danger from fire or an accidental detonation is always present, just as with conventional ammunition. High-explosive safety criteria developed for conventional weapons are equally applicable to nuclear weapons, whether or not any nuclear material is present.

Electrical and Mechanical Components

In addition to high explosive hazards, there are also electrical and mechanical safety aspects of nuclear weapons. The same observance of established safety criteria must prevail with respect to the handling and testing of electrical, electronic, and mechanical components of nuclear weapons. The precautions used with high voltage components are also applicable to nuclear ordnance. Similiarly, conventional mechanical safety precautions for handtools, power tools, and power operated handling equipment equally apply.

Nuclear Components

All personnel assigned to work with nuclear weapons must receive special training in the handling, stowage, and accounting methods peculiar to nuclear components. Prior to such training they must possess at least a Secret clearance based on a background investigation.

Although nuclear weapons are designed to prevent a nuclear yield in case of an accidental detonation of a nuclear weapon, there is still a dangerous radiation hazard unless safety procedures are followed. The Department of Defense (DOD) and the U.S. Atomic Energy Commission (AEC) have specially trained personnel to deal with all aspects of accidents involving nuclear weapons. For example, an explosive ordnance disposal school trains personnel in all phases of high explosive recovery or disposal in case of an accident, and only trained personnel are authorized for this task.

Nuclear Weapons Publications

There are publications promulgated by the Joint Atomic Weapons Publication System. Generally, all such publications are assigned an AEC-DNA number; those publications which are for the Navy have, in addition, a Navy Special Weapons Ordnance Publications (SWOP) designation.

Publications for nuclear weapons and related equipment are: General Information or Definitions (SWOP4-), Reports (SWOP5-), Safety (SWOP20-), Assembly (SWOP35-), and Maintenance (SWOP 40-) series of publications. For example, Navy SWOP 20-1 is a publication on explosive safety.

NUCLEAR WEAPON TERMS AND DEFINITIONS

When working in the field of nuclear weapons, special terms and definitions are used by Army, Navy, Air Force and the Atomic Energy Commission for all nuclear weapons components, weapon testing and handling, and nuclear weapon accidents. These terms and definitions are listed in SWOP 4-1. Some of the definitions used by the GMG are:

Nuclear Weapons Acceptance Inspection (NWAI)

A NWAI is a Navy inspection of a prospective nuclear capable activity or one previously decertified. This inspection is conducted by Navy inspectors to determine an activity's readiness to perform those technical, administrative, and logistical procedures directly related to nuclear weapons. Successful completion is a prerequisite to handling weapons.

Technical Standardization Inspection (TSI)

A TSI is a nuclear weapons technical inspection of service units conducted under the direction of the Defense Atomic Support Agency. The inspection is made to determine the degree to which a unit is adhering to prescribed procedures regarding technical operations and weapons system safety rules. The TSI establishes a safe and secure environment for nuclear weapons and provides essential administrative and logistical support in accomplishing the technical portion of its nuclear weapons mission.

Navy Technical Proficiency Inspection (NTPI)

A NTPI is a technical inspection conducted by Navy inspectors of Navy nuclear weapons activities to determine their capabilities, as appropriate, in the storage, testing, assembly, maintaining, handling, and loading of nuclear weapons.

Broken Arrow

Broken Arrow is a term used in the DOD to identify and report an accident involving a nuclear weapon, warhead, or nuclear component. In the Navy this includes a "significant incident" as defined in DOD Instruction 7730.12.

A nuclear weapon accident is any unplanned occurrence involving loss or destruction of, or serious damage to, nuclear weapons or their components which results in a actual or potential hazard to life or property.

Bent Spear

Bent Spear is a term used in the DOD to identify and report a nuclear incident involving a nuclear weapon, warhead, or nuclear component.

A nuclear incident is an unexpected event involving a nuclear weapon, facility, or component resulting in any of the following, but not constituting a nuclear weapon accident. An increase in the possibility of explosion or radioactive contamination. Any errors committed in the assembly, testing, loading, or transporting equipment, or the malfunctioning of equipment and material which could lead to an unintentional operation of all or part of the weapon arming or firing sequence, or which could lead to a substantial change in yield, or increased dud probability. Any act of God, unfavorable environment, or condition resulting in damage to the weapon, facility, or component.

ASROC TRAINING

Personnel handling ASROC missiles receive general team training using ASROC training and dummy missiles as aids. The following is a general outline of missile handling procedures that can be performed to train shipboard personnel prior to an NTPI.

1. Missile uncanning
2. Missile pickup with loader crane

3. Loading of missile into launcher cell
4. Unloading of missile from launcher cell
5. Missile pickup with trolley hoist
6. Loading of missiles into ASROC magazine storage rack
7. Missile readiness checks and other missile tests when training missile is in launcher cell
8. Unloading of missile from ASROC magazine storage rack
9. Missile off loading procedures
10. Operation of depth charge ARM/SAFE switch (when missile is in launcher)
11. Installation of depth charge power supply (when missile is in launcher)
12. Nose cap replacement
13. Cable assembly removal and inspection
14. Thrust neutralizer removal and replacement
15. Packing of missile in container

DEMOLITION AND EXPLOSIVES

Personnel using demolition materials must be specially trained for this work. They must be fully acquainted with the characteristics and types of explosives used with the types and operation of accessories, and with demolition techiques. Under NO circumstances should untrained personnel attempt to use this rate training manual or any other ordnance pamphlet or ordnance instruction as a text for performing any type of demolition work.

This section is concerned only with those explosive charges that are deliberately placed by hand to destroy, or otherwise make unusable to the enemy, material dangerous to our own personnel. Demolition materials commonly are issued to ships of the fleet to destroy cryptographic equipment in cases of a loss of a ship. Each ship has a destruct bill which is used to ensure that no equipments or documents are left intact prior to a ship's complete abandonment. In some cases, special demolition kits are issued where special weapons and equipments are employed.

As a Gunner's Mate aboard ship you may find yourself responsible for the storage, maintenance, and issue of demolition material, and you may also be called upon to assist in demolition work both ashore and afloat. For this reason, this section on demolition and explosives has been included in this manual. You are not expected to be an expert on demolitions after reading this chapter. However, in cases where specially trained teams are not available for demolition work and in cases of emergency, you may be called upon to conduct demolition operations related to destruction and to scuttling operations aboard ship.

DEFINITIONS USED IN DEMOLITION WORK

Armed. The term is applied to a fuze or firing device that is ready to be activated by being treated in a particular manner. When arming has taken place, detonator safety and the effects of any safety switches or safety pins have been removed.

Blasting Cap. A blasting cap is a detonator consisting of a cylinder which has one or more highly sensitive explosives enclosed at one end. The cap can be initiated electrically or from a spit of flame.

Electric Blasting Cap. An electric blasting cap contains a base load of a high explosive plus a primer charge and igniter. The electrical firing element consists of two insulated leg wires connected by a bridge wire embedded in the igniter. This bridge heats to incandescence when electric current is applied, and fires the cap.

Delay Electric Blasting Cap. A delay electric blasting cap is an electric blasting cap that has a burning delay train between the first flash (igniting) compound and the initiating explosive. A succession of explosives, with various delays, can be caused by these caps, even after the first explosion has destroyed the electric firing wires.

Nonelectric Blasting Cap. A nonelectric blasting cap does not have the electric wiring but has open space at one end of the cylinder, which can be closely fastened or crimped to a fuse or onto the snout of a coupling base of a firing device. The detonation in these caps is caused by a spit of flame.

Demolition Charge. A demolition charge is any hand-placed explosive charge used primarily for its blasting or shattering effect. A standard demolition charge contains a standard threaded activator well or equivalent, allowing the charge to accept and be fired by blasting caps held in place in the activator well.

Demolition Material. Demolition material, in the sense used here, means demolition charges and various items of equipment used with them. Demolition bombs are not included in demolition material.

Demolition Outfit. A demolition outfit is a combination of demolition items that may be used most effectively in such a combination. Some outfits consist of items of frequent general use in field installations. Others contain special tailor-made demolition equipment required for a specific, planned demolition installation.

Detonator. Detonator is the name applied to components, or devices, that can be used to initiate detonation from a stab or mechanical blow, from heat, or from a spit of flame. Detonators used in demolition work are containers loaded with initiating explosives, a base charge (sometimes called compound detonators), and sometimes blasting caps. Detonator pellets are components of detonators, fuzes, or initiators. A delay detonator is the name sometimes applied to a delay-type firing device with blasting cap permanently attached.

Detonating Cord (Primacord). Detonating cord consists of flexible tubing having a core of high explosive for carrying detonation from one end of the cord to the other.

Detonator Safe. Detonator safe is the condition of an explosive device when the initiating detonator is separated or blocked from the remainder of the explosive train, so that detonation of the initiating detonator will not cause detonation of the remaining portions of the explosive train. Detonator safety cannot be attained by isolating the detonator from influences that might cause its detonation (such as opening or shorting an electric firing pin circuit, or by inserting a positive safety pin). Detonator safety requires isolation of the detonator from the remainder of the explosive train.

Firing Device. The term firing device applies to a device for causing the explosion (firing) of demolition charges. This is accomplished either directly or through the effect of the device on a blasting cap, electric detonator, or detonating cord. Explosion is caused when certain conditions are met, such as completion of a time delay, disturbances, impact, or inertia. The Navy firing device used in demolition work is called demolition firing device.

Electric Firing Device. An electric firing device is used for electrically initiating the first flash (first flame) in the chain of events leading to detonation. The device closes an electrical switch or generates electricity when the selected time arrives or event takes place.

Mechanical Firing Device. A mechanical firing device is used for initiating by percussion or friction, the first flash (first flame) in the chain of events leading to detonation. This device moves a firing pin or friction wire rapidly when the selected time arrives or the selected event takes place. Mechanical firing devices initiate both instantaneous and delay functioning.

Standard Mechanical Firing Device. A standard mechanical firing device is used to prime a standard demolition charge. These devices may be divided into three classes; those that have a removable coupling base, which converts the impact of a firing pin into a spit of flame; those that furnish a spit of flame from a permanently attached base; and those that have a base and a blasting cap permanently attached to them. Those in the last class are sometimes known as delay detonators.

Fuse. A fuse is a slow-burning powder-filled cord that carries flame to an explosive or combustible mass after burning for a predetermined time.

Fuze (Not To Be Confused with Fuse). The term fuze is a general one applying to any device that causes detonation, expulsion, or ignition upon the fulfillment of certain conditions, such as completion of a time delay, certain disturbances, impact, or inertia. The term is usually used in connection with bombs, projectiles, pyrotechnics, or rocket heads. In demolition work, the term fuze is sometimes used interchangeably with the term firing device.

Primer. The term primer has a number of meanings, depending on its application. In demolition work, the term primer can apply to the material used for priming a charge. The term percussion cap primer when used in connection with demolitions, applies to the explosive-filled portion of a coupling base. In connection with guns, the term primer refers to the device that ignites the propelling charge. The term primer-detonator is used sometimes to refer to a stab-type detonator. The primer-detonator is initiated by a firing pin.

Priming. The term priming means the preparation for explosion of a relatively insensitive explosive charge by fixing it to other more sensitive material or devices. An example of priming is the installing of a blasting cap in a demolition charge.

DEMOLITION DEVICES

Many types of demolition devices, explosive and incendiary, have been developed to destroy combustible classified material by burning and classified equipments by melting or shattering. The Navy has adopted some demolition devices to be used in areas aboard ship where classified, cryptographic, nuclear, and weapon systems equipments and documents must be destroyed in cases of emergency.

Demolition devices are classified by their purposes; those used to destroy bulk type equipments, and those used for emergency destruction of classified materials. On ships that are required to carry such demolition devices, you as a Gunner's Mate may be required to maintain these devices to ensure that they are ready for use in time of emergency.

This discussion of demolition devices will be in two sections: the first section provides information and procedures on the devices necessary for the destruction of classified material and equipments; the second section provides information and procedures on demolition charges used for bulk (major) type destruction.

Emergency Destruction Stages

Emergency destruction of classified matter is generally carried out in three stages: Priming, arming, and firing.

1. PRIMING. Priming is carried out when a situation develops in which capture of classified material becomes probable. Priming consists of assembling the classified material to be destroyed, placing it in burning containers, or placing incendiary devices or oxidizers in place with shorting plugs installed.
2. ARMING. Arming is carried out when the capture of classified material is imminent. Arming procedures include hooking up to an electrical ignition system and removal of local shorting plugs.
3. FIRING. Firing includes evacuation of all personnel from the general area, removal of the master shorting plug from each circuit, and ignition of the incendiary devices.

Emergency Destruction Systems

All emergency destruction systems consist of an ignition system, burning containers, and one or more of the following incendiary devices:

INCENDIARY DESTRUCTOR TH3, ELECTRO-MOD. — A thermate-filled cylinder (2-1/2 inch diameter x 4-1/2 inch height), electrically initiated, which will produce about 1-1/2 lbs. of 4000°F molten slag in about 30 seconds. Its principal use in the destruction of classified documents is in initiating the M3 document destroyer, to fuse electronic equipment, or to start fires.

The Destructor, Incendiary, TH3, Electro Mod is the Grenade, Hand, Incendiary, AN-M14 modified for electrical ignition. The mechanical fuze of the grenade is replaced by a Mk 13 Mod 0 squib (see Fig. 12-6A). The squib wires are fitted with a connector and a shorting plug. The Destructor is packaged eight to a sealed, reusable ammunition box to eliminate accidental initiation by electromagnetic radiation.

Observe the following safety precautions when using the Destructor:

1. Stay at least 20 feet from a Destructor that is about to be ignited. For more than one Destructor, if the Destructor is being used in a closed space, evacuate the space.

2. Do not ignite the Destructor within 5 feet of flammable material that is not to be destroyed.

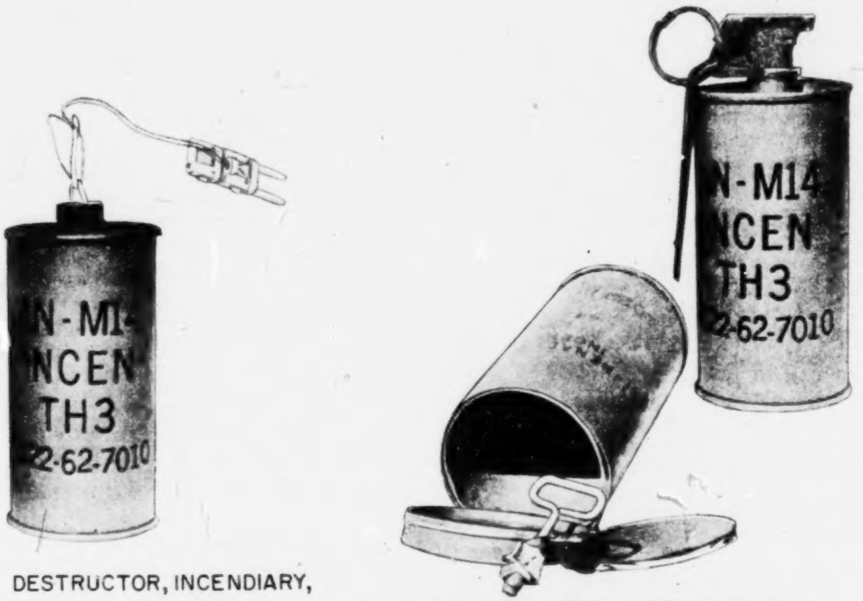
3. The destructor must not be altered. Any attempt to replace the squib is dangerous and is prohibited.

4. Confine firefighting efforts involving the destructors to holding fires ignited by thermate in check until the molten filling has cooled off. Sand, sodium bicarbonate, or dolomite mixtures (calcium magnesium carbonate of varying proportions) will smother thermate fires. Water is insufficient unless used in massive quantities.

5. Keep the Destructor in the storage container to prevent accidental initiation from electromagnetic radiation.

6. When using the Destructor, check that all RF levels in the area do not exceed those allowed for HERO unsafe ordnance as defined in NAVORD OP 3565.

7. The shorting plug should always be plugged in the connector. In the presence of electromagnetic radiation, keep the squib leads shielded.



DESTRUCTOR, INCENDIARY,
TH3, ELECTRO MOD

GRENADE, HAND, INCENDIARY, TH3,
AN-M14

53.319
Figure 12-6.—Destructor, Incendiary.

8. Treat burns caused by thermate like those caused by fire. Flood the burn with water and remove any particles from the skin. If the skin is broken, cover the raw area with first-aid dressing. For more serious burns, give the victim first-aid for shock, keep him quiet and warm, and transfer him to the care of medical personnel. No special first-aid treatment is required for injuries resulting from thermate burns.

INCENDIARY GRENADE AN-M14.—A thermate-filled cylinder (2-1/2 inches diameter x 4-1/2 inches high), mechanically initiated, which will produce about 1-1/2 pounds of 4000° F molten slag in about 30 seconds. (See Fig. 12-6B.) The Grenade weighs 2 pounds and is filled with 1.65 pounds of TH3. The Grenade uses the M201A1 standard grenade fuze, which screws into an adapter in the top of the grenade. The Grenade comes packed in a tear-strip can, with 16 grenades overpacked in a wooden shipping box.

Use. The Grenade, Hand, Incendiary, TH3, AN-M14, gives off intense heat for starting fires or destroying light equipment. In destroying classifed materials, the Grenade can be used to initiate the M3 Document Destroyer, fuse electronics equipment, or start fires. With imaginative use the Grenade can be an effective and versatile demolition tool. It can melt thin steel and common non-ferrous metals; it can jam mechanisms by warping the components; it can weld properly prepared iron and steel. Examples: The grenade can destroy oil drums and shipping containers, engine water jackets or manifolds and metal ammunition boxes; it can jam weapon breech blocks; it can melt electric motor cage and rotor windings; it can set buildings or papers afire. Due to its burning characteristics and limited capacity, the grenade will not adequately destroy the contents of a file cabinet drawer or safe.

To use the grenade, place it securely in position. If necessary, fasten the grenade in place with a metal strap or ordnance tape, but do not rely on either fastener to hold the grenade in place while it is burning. To ignite the grenade, hold the grenade with the safety lever pressed firmly against the grenade. Pull out the safety pin, release the safety lever, and then move quickly to a safe distance. For remote firing, fasten the grenade securely in place, tie a lanyard to the ring on the safety pin, and run the free end of the lanyard to a safe firing location. After making sure the lanyard is not taut, hold down the safety lever with one hand and straighten the end of the safety pin with a pair of pliers so that the pin can be withdrawn easily. Now the grenade can be fired from a safe distance by a firm pull on the lanyard.

WARNING

Modification of the grenade for electrical ignition is not authorized for untrained personnel.

Observe the following safety precautions when handling the AN-M14 Grenade:

1. Stay at least 20 feet away from a grenade that is about to be ignited. For more than one Grenade or Destructor, increase the distance. If the Grenade is used in a closed space, evacuate the space.
2. Do not ignite the Grenade within 5 feet of flammable material that is not to be destroyed.
3. Do not use the ring on the safety pin for lifting and handling the grenade.
4. Never pull the safety pin out unless the grenade is to be ignited.
5. Do not strike the tip of the fuze or drop the grenade. Such actions may initiate the fuze.

DOCUMENT DESTROYER, EMERGENCY, INCENDIARY, M3.—The incendiary device comes in a packing drum 16-1/2 inches in diameter and 20-1/2 inches high. The total weight is 117 pounds. The drum contains five 19-pound packages of sodium nitrate compound pellets and an igniter charge bag containing a pyrotechnic mixture of sugar, charcoal, and sodium nitrate. The drum also contains a metal screen, a retaining band assembly, two M25 igniters and a box of safety matches.

Late models of the M3 Document Destroyer are packaged in a metal drum that can serve as a small burning container. This model also has the igniter charge packaged in four tear-top aluminum cans instead of a bag and has a wire retaining assembly to hold the screen in place on the burning container. Refer to Figure 12-7.

The Document Destroyer, Incendiary, M3 will quickly destroy paper or cardboard by burning. The Destroyer can thoroughly burn up to 75 pounds of paper. In normal use, the classified papers to be destroyed are placed in a 55-gallon drum. The Document Destroyer igniter charges and oxidizer bags are placed on top of the paper, and an M25 igniter sets fire to the contents of the drum. When necessary, matches can replace the M25 igniter. The Destroyer burns for about 10 minutes with a hot, high and violent flame.

As the Document Destroyer supplies its own oxidizer, the Destroyer can burn papers in closed spaces, file cabinets and safes.

When electrical ignition is desired, a Destructor, Incendiary, TH3, Electro-Mod can set off the Document Destroyer.

Observe the following safety precautions:

1. The Document Destroyer burns quickly and violently; keep a safe distance from the fire. If it is used in a closed space, evacuate the space.

2. Large volumes of black smoke will result from the burning. The smoke is acrid but not toxic.

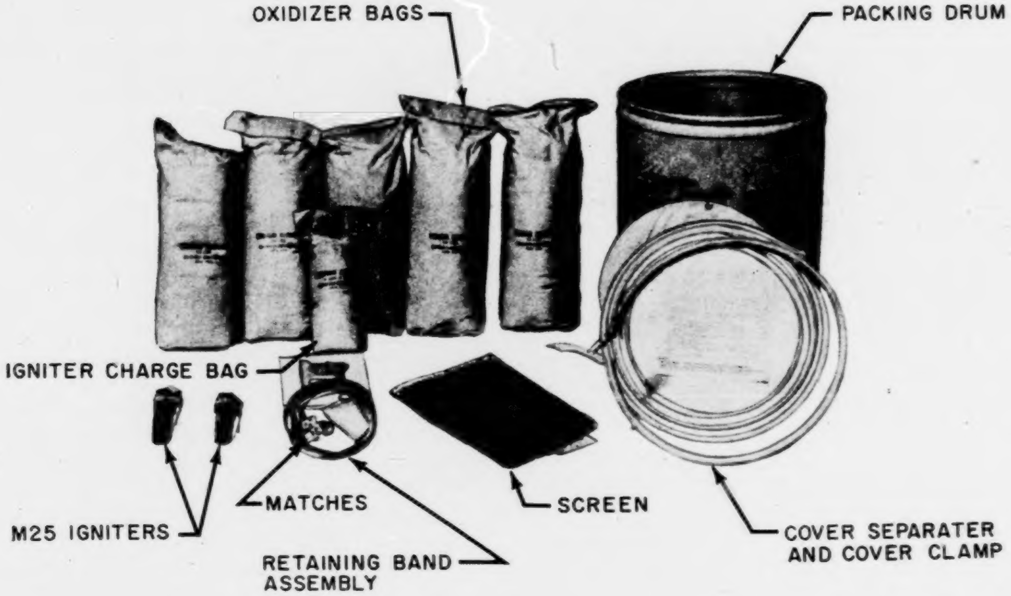
3. The Document Destroyer must be stored away from fire hazards and open flames. Sodium nitrate is a powerful oxidizing agent, and if involved in a fire, it will cause the fire to burn hotter and faster.

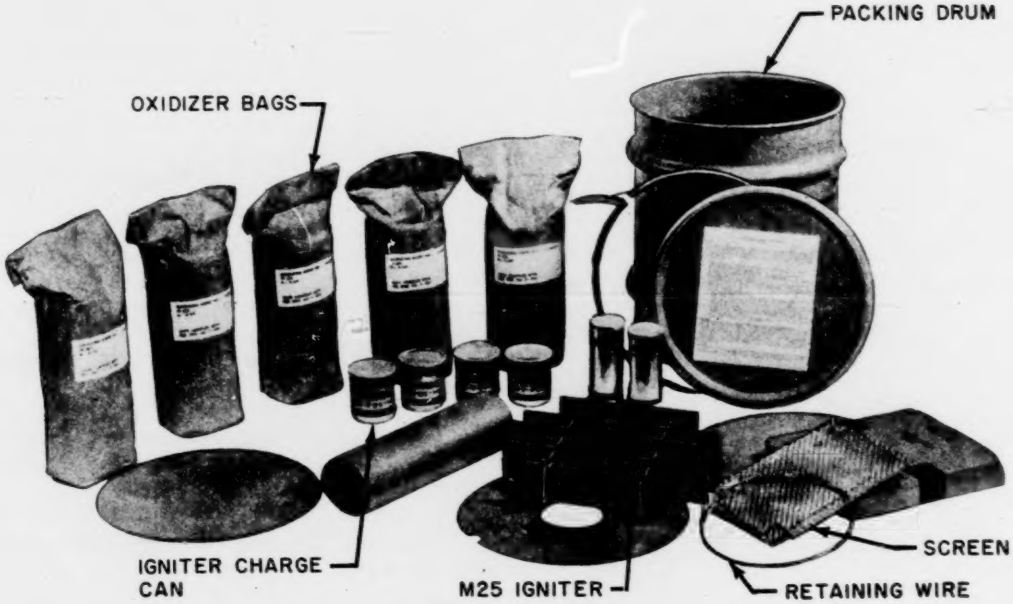
4. The device is designed primarily for use out-of-doors since flames often go 25 feet high.

Destruction of Electronic Equipment

There are three methods for destroying electronic equipment. One method uses the destructive action of a thermitic device while the others involve a fire supported by sodium nitrate.

When a thermitic device is used without an oxidizer, place the incendiary on top of the electronic equipment to be destroyed so that the molten slag will flow over the entire chassis. The 4000° F slag will destroy all wires, solder connections and printed circuits. Although secondary fires will result, the primary destructive effect comes from the molten slag. While this method works well with lightweight aluminum chassis, steel or heavy gauge aluminum chassis may withstand the effects of the slag so that not all of the circuitry is destroyed beyond recognition.


OXIDIZER BAGS
PACKING DRUM
IGNITER CHARGE BAG
MATCHES
SCREEN
M25 IGNITERS
RETAINING BAND ASSEMBLY
COVER SEPARATER AND COVER CLAMP


PACKING DRUM
OXIDIZER BAGS
IGNITER CHARGE CAN
M25 IGNITER
SCREEN
RETAINING WIRE

53.320

Figure 12-7.—Document Destroyer, Emergency, Incendiary, M3 (both versions).

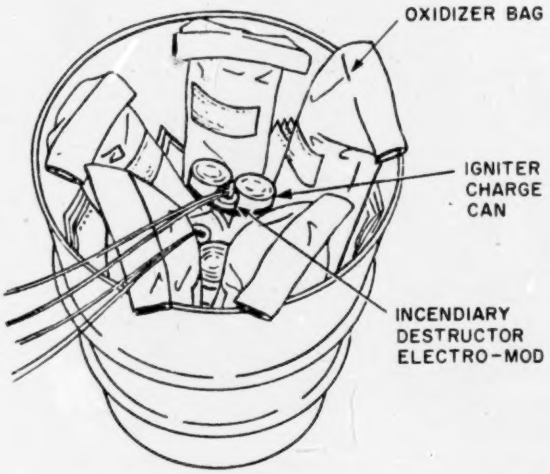
The recommended method of destroying steel or heavy gauge aluminum equipment is to fill the entire chassis with loose sodium nitrate from an M3 Document Destroyer and then start a fire with a thermitic device.

The preferred method of destroying electronic equipment is to remove printed circuit boards and other classified components and to destroy them separately in a burning container with an M3 Document Destroyer.

Emergency Destruction of Publications, Circuit Boards, and Other Removable Classified Material

When directed to PRIME, use the following procedures to prepare classified material for destruction:

1. Take a 55 gallon drum and loosely pack in up to 70 pounds of classified material. Be sure that the drum is a safe distance from other flammable material. Unpack the M-3 Document Destroyer. Take the five Oxidizer bags and place them in a circle on top of the classified material (See Figure 12-8.)
2. When directed to ARM, tape two AN-M14 Grenades or two Electro-Mod Incendiary Destructors to the igniter charge bag. If the Document Destroyer contains four igniter charge cans instead of an igniter charge bag, tape two igniter charge cans to each Grenade or Destructor. If M-25 igniters or matches will be used to start the fire, place the igniter charge bag in the burning container, If igniter charge cans come with the Document Destroyer and M-25 igniter or matches will be used, open the charge cans, cover the tops with plastic covers and place the cans upside down in the burning container.
3. If destructors are used to set off the fire, when ARMING plug the connectors into the local plug-in box current source. If grenades are used, run the lanyards to a safe firing location.
4. Secure the screen to the top of the burning container.
5. If destructors are used, remove the shorting plugs from the destructor connectors. Cover bare connecting pins with tape to prevent a short circuit.
6. Evacuate all personnel from the area or space.



53.321
Figure 12-8. — M-3 Document Destroyer in burning container.

Manual Ignition

The recommended method for manually initiating Document Destroyer M3 is with the AN-M14 Grenade. In these cases, fasten the grenade to the igniter bag or igniter box so that the grenade can be ignited remotely.

Use the following procedures for manual ignition of destruction devices:

1. Install the destructive device by following procedures contained in this chapter, except those procedures concerning electrical connections.
2. When directed to ARM, tie a lanyard to the ring of the safety pin of the mechanical fuze.
3. Make sure the safety pin is secure in the fuze.
4. Lead the free end of the lanyard to a protected firing location.
5. Make sure the lanyard is not taut.
6. Hold down the safety lever on the mechanical fuze and with a pair of pliers straighten the safety pin so that it can be withdrawn easily.
7. When directed to FIRE, evacuate all personnel from the area or space, get back a safe distance and pull the lanyard.

When all destruction devices are armed and all spaces or areas have been evacuated, use the following procedures when ordered to FIRE:

WARNING

When melted aluminum from equipment chassis, magnetic type reels or scattered paper is mixed with an oxidizer, an explosive situation exists. Prepare to abandon ship or evacuate the area if large scale destruction of equipment is to take place.

CRYPTOGRAPHIC AND NUCLEAR EQUIPMENTS

Cryptographic Equipment Destroyers are used for destroying cryptographic equipment made of plastic and wiring by melting, burning, and severing connections. There are two types of equipment destroyers used by the Navy, M1A2, TH4 and M2A1, TH4. Both are thermite incendiary types housed in a sheet metal box. They are fitted with one or two electric squibs and one mechanical fuze. When ignited by the mechanical fuze, a delay element in the ignition train of the fuze provides a delay of 1.2 to 2.0 seconds; there is no delay when ignition is by the electric fuze. The main differences in the destroyers are their size and burning time, the M1A2 burns for approximately one minute and the M2A1 for 45 seconds. They are packaged for shipment in an aluminum container to eliminate accidental initiation by electromagnetic radiation.

Since cryptographic areas require special security clearance, personnel in ratings associated with cryptographic equipment are responsible for their destruction during emergency situations. The GMG is responsible only for the stowage, maintenance, and issue of cryptographic destroyers. OP 2212 Vol 1, Demolition Material, describes in detail their use both afloat and ashore.

Special nuclear weapons destruct kits are available for use on nuclear components and weapons in cases of emergency. The materials needed to implement destruction depend on the type of weapon and other items being destroyed and should be obtained accordingly. NAVY SWOP 50-8, Emergency Destruction of Nuclear Weapons, contains tables listing nonexplosive, nonexpendable items normally used for emergency destruction; nonexplosive, expendable items used with demolition kits; and explosive, expendable items used with the kits for emergency destruction procedures. Details concerning the methods of destruction of nuclear components are not discussed here due to their security classification.

DEMOLITION CHARGES AND OUTFITS

Up to this point we have been discussing demolition devices used for the destruction of classified equipments and documents. In the next few pages we shall take up demolition explosives and accessories used for general and major demolition operations.

All explosives used for demolition work by the Armed Forces are high explosives. The principal types commonly used by the Navy are TNT, tetrytol, dynamite, Petn, and plastic explosives. The types of charges issued for use by naval forces are demolition outfits, (which are issued as complete sets), demolition blocks, demolition shaped charges, and some special underwater obstacle clearance demolition outfits. Any one of the explosives mentioned could be used in demolition charges to set off a charge, however, the choice of the wrong methods of firing demolition charges could result in a possible premature firing or in a misfire or an unavoidable expenditure of time or personnel. For this reason safety precautions and procedures for setting up demolition firing systems using nonelectric blasting caps and safety fuse, electric firing, and detonating cord firing systems will be discussed. The types of demolition charges, demolition outfits, and demolition accessories issued to the fleet are explained in GMG 3/2, NAVPERS 10185, and OP 2212, Demolition Materials, and will not be repeated here.

FIRING SYSTEMS

Since safety is paramount, all specific safety precautions applicable to demolition explosive charges and equipment must be observed. In addition, the following general safety precautions must be observed during demolition operations, regardless of the type of firing system used.

WARNING

When setting up a firing system, observe general safety precautions listed herein, as well as safety precautions applicable to specific charges and items of ordnance.

1. Carry out all safety precautions and other instructions for a demolition operation with utmost care and thought.

2. Do not handle explosives carelessly.

3. Do not divide responsibility for preparation, placement, and detonation of charges. Make one person responsible for supervision of entire project and appoint alternates to take his place if necessary. Personnel who prepare charges should complete each one before starting another.

4. Do not leave explosives unguarded. Keep them under lock and key, and do not give the key to an irresponsible person.

5. Do not attempt to investigate the contents of blasting caps or try to open them.

6. Do not carry caps loose in the pocket.

7. Keep blasting cap box covered.

8. Do not smoke or allow an open flame near explosives.

9. Do not leave explosives or caps exposed to direct sunlight or any other source of heat.

10. For stowage purposes, treat a blasting cap assembled with detonating cord, with a charge, or with both as a blasting cap having the total explosive strength of all components.

11. Make sure that there is no dirt in the activator well before inserting a blasting cap or a firing device.

12. Do not force a blasting cap into the threaded activator well by forcibly screwing in the priming adapter or the firing device.

13. Do not attempt to fire demolition materials except when prepared to fire them successfully the first time.

14. Handle a misfire (after the necessary waiting period) by placing, if at all possible, additional charges near the original charges.

15. Use dual firing systems whenever possible, particularly when there is a possibility of unexploded charges being left hidden, tamped in the ground, or left unrecovered in shallow water.

16. Use additional priming, if practicable, when conducting training operations with demolition charges primed by cap and fuse or with charges to be buried in the ground, hidden, or placed where recovery would be difficult for any reason. This can be accomplished by means of an electric blasting cap or by a long line of detonating cord led from a place of safety. If this is not practical, prior to any attempt to fire, place another charge close enough to the first charge so that detonation of either will detonate the other.

17. Use the safest method of firing in training, testing, and disposal operations in which a particular method of firing is not required.

18. Do not use short delay times, unless required in training, testing, or disposal operations in which firing by safety fuse or firing device is required.

19. Do not use larger charges, shorter firing wires, or greater exposure of personnel than is necessary when training or testing.

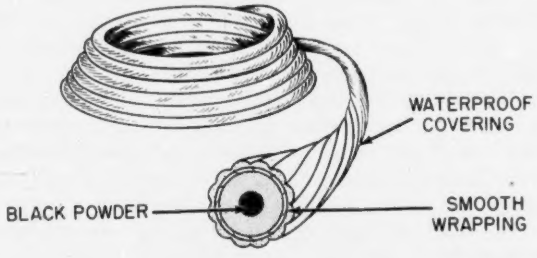
FIRING WITH CAP AND FUSE

In this section we will give you some general directions for using nonelectric blasting caps, crimped onto time blasting fuses, to fire demolition charges. Under some combat conditions this is the best way to fire a charge. The materials you need are light in weight, and you can assemble them quickly. And you can make up your demolition assemblies in advance, before you get to the scene of action.

But of all the usual ways to set off a demolition charge, this one is probably the most dangerous. For one thing, there is always the danger of a premature explosion, or a hang-fire. For another, you have to make your getaway while the fuse is burning, and there's always a chance you'll stumble and fall. If time permits, and you have the equipment, it is always safer to use the electric firing system.

Characteristics of Blasting Time Fuse

The Navy issues blasting fuse, figure 12-9, that burns at the rate of ABOUT 40 seconds a foot. Many factors affect the burning rate, including altitude, exposure to moisture, and how much of the fuse is confined.



53.156
Figure 12-9.—Coil of blasting fuse (safety fuse).

For these and other reasons, you should burn a sample 6 foot section of the fuse, noting its burning time. (If you are going to use less than 6 feet of fuse, it isn't safe to estimate burning time this way. Make a special test using a sample fuse of the actual length you plan to use on the charge.) Lay out the fuse under the same conditions you expect to have it laid out for the actual firing, and light it the same way.

Remember, blasting fuse is packed with loose grains of black powder. During handling, some of this powder is almost certain to sift out from the cut end. For this reason, before you set up your charge, cut a 6 to 12 inch length from the end of the coil and throw it away.

Preparing the Cap and Fuse for Use

Here are directions for preparing the cap and fuse. The best way to prevent accidents is to follow these directions exactly.

1. Cut off a short length from the end of the fuse coil, and throw it away.

2. If you haven't tested the fuse burning rate recently, make a new test with a 2-foot length. If you're going to use less than 2 feet of fuse, make a test with the length you expect to use.

3. Cut off the desired length of fuse. If the cutting edges of the cap crimper aren't keen, use a clean sharp knife. Cut the fuse square across—not at an angle.

4. Now, if you're going to use a priming adapter, push one end of the fuse through the hole at the flat end of the adapter.

5. Examine both ends of the fuse, to be sure no powder has sifted out. The powder should be flush with the end of the fuse.

6. Take one nonelectric blasting cap from the box. Be careful; it's more dangerous than it sounds. Tilt the cap box slowly into the palm of your hand, until one cap starts to slide out. Withdraw this cap carefully. Never use a stick, or a pointed instrument, to pick caps out of the box.

7. Before crimping a nonelectric cap onto time fuse, examine the cap for foreign substance and moisture. In case of foreign substance in the cap, turn cap so that its fuse end is down and shake it gently. Do not tap cap with or against a hard object. Do not blow into cap. If foreign substance cannot be removed by gentle shaking, use another cap. In case of moisture in the cap, use another cap.

8. Now, gently but firmly, push the end of the fuse into the cap; it will go in about seven-eighths inch. Don't force the fuse if you can't push it in easily. And push it straight—don't twist it. Any friction between the end of the fuse and the detonating compound in the cap is likely to fire the cap.

9. Now you're ready to crimp the cap onto the fuse. Hold the fuse between the thumb and third finger of your left hand. Put your forefinger over the end of the cap. Slide your thumb and forefinger up to the open end of the cap to guide the crimper. Crimp close to the open end; crimping near the explosive may detonate the cap. If you use your thumb and third finger to guide the crimper, you can crimp a cap properly even in the dark.

(If you're going to put the charge in a damp place, it's a good idea to apply cap-sealing compound to the fuse before you push it into the cap. Spread a little of the compound around the outside of the fuse, at the place where the crimp will be. Don't dip the end of the fuse in sealing compound. Don't let the compound touch the cut end of the fuse, or the detonating compound in the cap.)

10. Now insert the cap assembly in the demolition charge. If the charge has a threaded activator well, you'll be using a priming adapter. Slide the adapter a short distance up the fuse, AWAY from the cap. Insert the cap in the activator well. (It must go in freely; don't force it.) Gently slide the adapter down the fuse, and screw it into the threads of the activator well. Never use the priming adapter to force the cap into the well.

Lighting the Fuse

There are several ways to light the fuse safely. The most reliable is to use the M2 or M60 fuse lighter. But when you use the fuse lighter, remember that it is waterproof. That means that it will hold in the gas coming from the burning fuse, causing a small pressure to build up in the fuse lighter. Thus, the first few inches will burn faster than you would expect. So, always allow a little extra fuse length when you use the fuse lighter.

If you have no fuse lighter, you can use a wooden match. When a match is used, split the end of the fuse, and place the head of the unlighted match in the powder train. (See figure 12-10.) The head of the match is left protruding slightly and is ignited by drawing the abrasive side of a match box across it.

Misfires

Don't try to light a time fuse for demolition unless you know you can do it right the first time. And here's an inflexible rule: After ANY attempt to light the fuse, scram. That rule has no exceptions. Sometimes the fuse smokes when it's burning; sometimes it doesn't and you can't be sure whether it's lit or not. After any attempt at lighting the fuse, get away to a safe place and stay there, even if you think the fuse isn't burning.

Wait until the longest estimated burning time of your fuse has elapsed. If the charge doesn't detonate by then, you'll know you have a misfire. Stay in a safe place; WAIT AT LEAST 30 MINUTES before you go back to investigate. (In actual combat, you may have to investigate almost immediately. But in any case wait as long as you can.)

Dual Firing Systems

A dual firing system will decrease the chance of a misfire. A dual firing system uses more than one cap and fuse, or more than one method of firing. If a misfire is likely to leave unrecovered charges hidden, or tramped in the ground, or lying in shallow water, then use dual firing whenever possible. If you use two separate fuses, be sure to cut one of them extra long. Light that one first, so you'll have time to light the second one safely.

During training operations with time blasting fuse, always use a dual firing system if possible. Your best bet is to prime one of the charges with an electric cap, and run the firing wires back to a safe place. Then, if the time fuse misfires, you can detonate the charge electrically without leaving your place of safety.

ELECTRIC FIRING

The electric firing method uses electric blasting caps with firing wires running to a distant source of electricity (usually a blasting machine, figure 12-11).

Electric firing is the safest method you can use. You control the detonation from a safe distance; you don't have to make a getaway from the vicinity of the charge; you don't have to make any guesses about burning time.

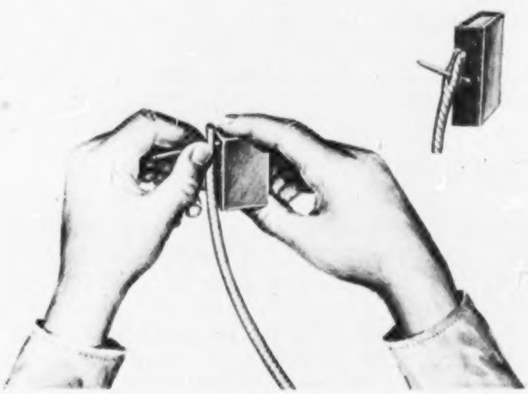


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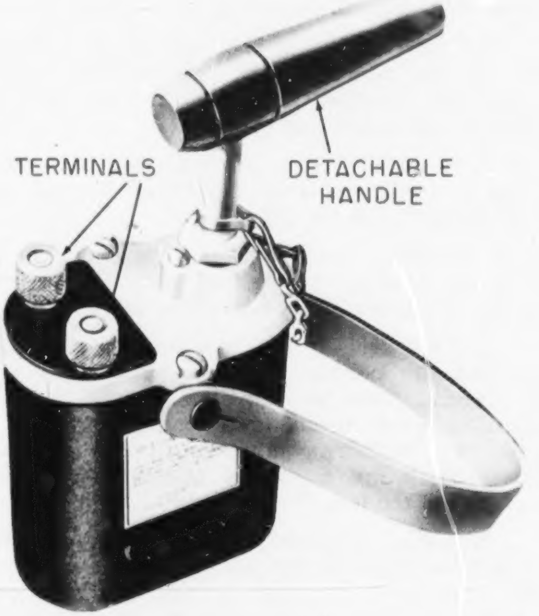
Figure 12-10.—Lighting Time Fuse with match.



29.87
Figure 12-11.—Ten-cap blasting machine.

The basic principle of electric firing is simple. When an electric current flows through a conductor, it generates heat. The amount of heat generated at any point depends on three things: the voltage drop at that point; how much current flows; how long the current flows. So, for successful electric blasting, you'll have to be sure that your source of electricity is powerful enough to fire all the caps you've wired in the circuit. And you'll have to make the resistance of your firing wires and splices as low as possible. That will leave most of the resistance, and most of the voltage drop, in the bridge wires of the caps.

Cap, Blasting, Electric, M6

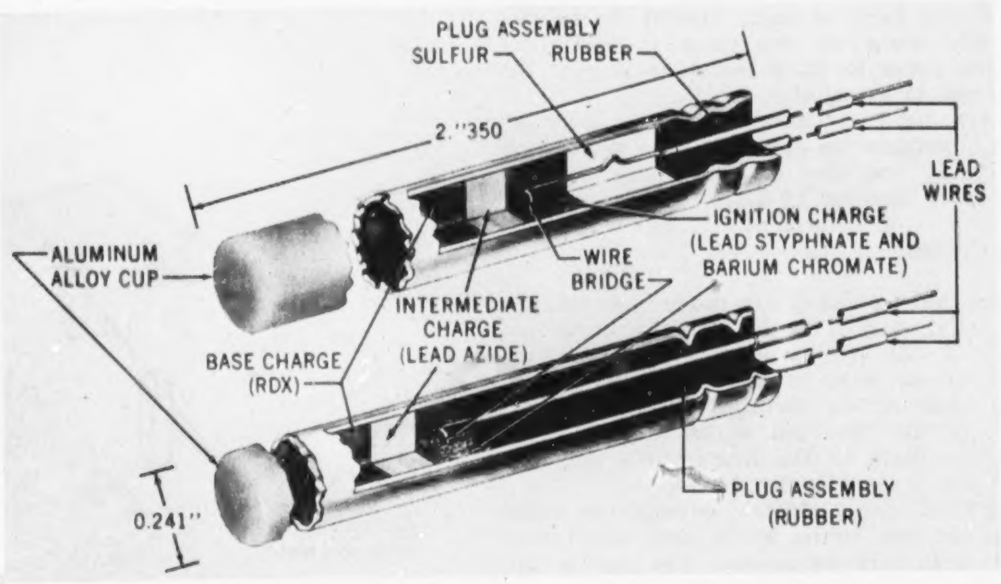
The Cap, Blasting, Electric, M6, figure 12-12, is used for initiating high explosives when a source of electricity such as a blasting machine or battery is available. This cap is designed to be inserted in cap wells and also is used as the detonating element in certain land mine fuzes.

The cap consists of an aluminum alloy cup containing a base charge of RDX, intermediate charge of lead azide and an ignition charge of lead styphnate and barium chromate. The lead wires extend through a rubber plug assembly or a cast sulphur and rubber plug assembly into the ignition charge where connected with a wire bridge. The leads are twelve feet long and copper tinned. The electrical characteristics of the M6 are so closely controlled that caps of this model, of different manufacturers, may be mixed in a firing circuit without causing misfires. A short-circuiting tab or shunt fastens the leads together to prevent accidental electric firing of the cap. A minimum current of 0.5 ampere is required to assure detonation of the cap when used in a firing circuit.

Electric Wiring

Poor electric connections in a demolition circuit are likely to cause misfires. For that reason, ONE person who thoroughly understands electric firing circuits should be responsible for ALL wiring. He should make all the splices himself. These are the main points to look for:

1. Be sure that all the caps are included in the circuit.
2. Be sure that all the splices between cap wires, connecting wires, and firing wires are properly made.



53.157.2(53C)
Figure 12-12.—Cap, Blasting, Electric, M6.

3. Be sure there's no chance of a short circuit. Carry the handle of the blasting machine in your pocket. That will reduce the possibility of accidental firing while you're near the charge.

4. When wiring up a circuit, make sure there's no strain on the leg wires that might pull them out of the caps. Be especially careful when the firing wire is partly unsupported, or where it passes through water and may be moved by wave action. If necessary, tie the firing wire, or the leg wire, or both, to the charge.

If you're going to splice two insulated wires, strip off about 3 inches of insulation from the end of each wire. Be sure to remove the enamel, as well as the other insulating material. Clean the bare wires by scraping them lightly with the back of a knife blade. (But don't cut or weaken them.) If the wire is stranded, twist the small strands together to make a single lead.

To splice (fig. 12-13), join the two wires with several twists, bend the free ends toward each other, and twist them together to make a "pigtail." Then bend the pigtail to one side, so it will lie along the wire.

If there's any chance that your splice will touch the ground, or some other conductor, insulate the splice by wrapping it with friction tape. If you have no tape, support the splices on a dry stone or dry piece of wood. (But if you're going to tamp moist earth over the splice, tape is essential.)

If you have to splice two pairs of wires together, stagger the splices so they can't touch each other, and bind the two wires together with cord or tape (fig. 12-13).

Firing Circuits

When you're going to fire two or more charges electrically, you will usually wire them in series. You splice one wire from the cap in the first charge to one wire of the cap in the second charge, and so on through all the charges, until only the two end wires are left. And you splice these to the firing wires that lead to the blasting machine (fig. 12-14).

CAUTION: Stray electric currents or static charges in the firing wires have sometimes caused premature explosions. You can be safe from this kind of accident only if you short out any stray currents. Twist the bare ends of the firing wires together, at each end of

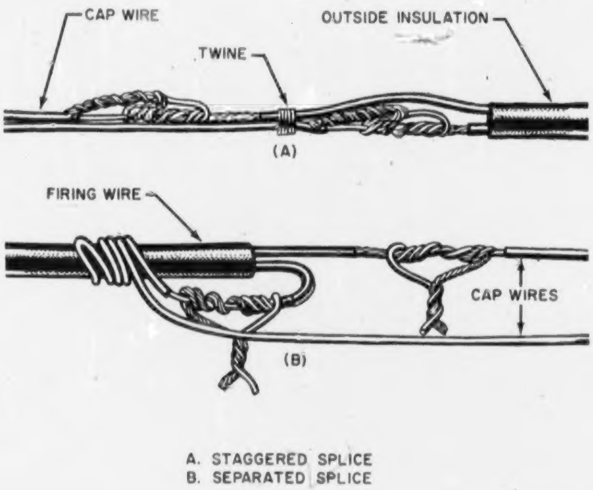


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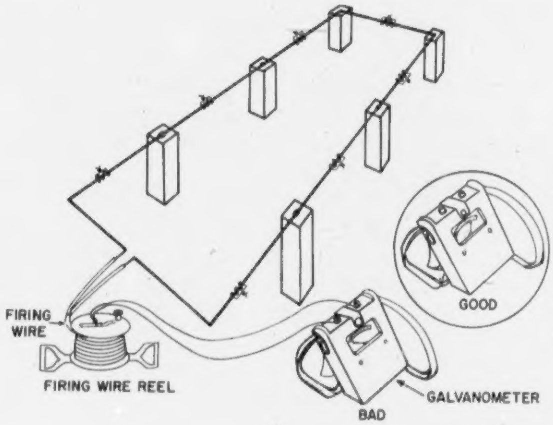
Figure 12-13.—Connecting two pairs of wires.



53.170

Figure 12-14.—Testing the firing circuit.

the cable. Don't separate the wires at the firing end until you're ready to splice them into the circuit. And don't separate the wires at the reel (input) end until the rest of the circuit is completely wired, everybody is out of the danger zone, and you're ready to blast.

Figure 12-14 shows the usual way to wire up a series circuit. One of the wires from the cap in one charge is spliced directly to a wire from the cap in the next charge. Of course, if the cap wires aren't long enough to meet, you'll have to use another piece of wire between them.

How many caps can you wire up in one circuit? That depends on the resistance of the circuit, and on the strength of your electric power source. Don't put too much stock in such designations as "10-cap blasting machine" and 50-cap blasting machine." Those names apply to "average" conditions. If your circuit has more than normal resistance, because of poor splices or extra long wires, the blasting machine can't live up to its designation. And if your blasting machine isn't strong enough for the circuit you've wired up, you're bound to have misfires.

Charges can be wired in parallel or in series-parallel, but both these types of circuits take a lot of power. You can use them when you have access to a power or lighting line for firing, but they won't work with a blasting machine. Besides, you have to match the resistance of all the parallel branches, so you'd better not try these circuits unless you're a wiring expert.

Testing the Circuit

The procedures for testing the firing circuit were covered previously. To review this important job briefly, here are a few of the highlights.

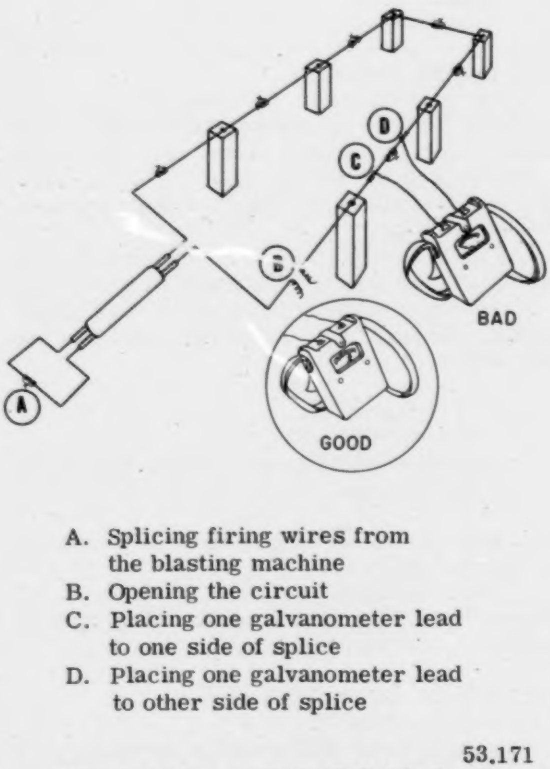
You will use only the galvanometer to test for shorts and opens. You studied these procedures in chapter 9 of this text, using an ohmmeter on ordinary gunnery circuits. The tests you are going to make on your demolition firing circuit with a galvanometer are similar to those discussed in chapter 9.

First, before connecting the firing wire to the charges, test the wire for shorts. Make sure that the ends of the firing wire are separated; then touch the two wires at one end to the galvanometer terminals. The needle should not move. If it does, you have a short. You will have to find and repair it. To test for opens in the firing wire, twist the wires together at one end and touch the other ends to the terminals of the galvanometer. The needle should show a wide deflection. If it doesn't move at all, you have an open circuit. If it moves just a little, there is a point of high resistance in the wire.

After you have repaired all breaks and short circuits, test the wire again.

Now you can connect the firing wires to the charges and test the circuit as a whole. When you touch the ends of the firing wire (at the reel end of the cable) to the galvanometer terminals, you should get a needle deflection (fig. 12-14). The needle won't move as far as it did when you tested only the firing wire, because of the resistance of the additional wiring and caps. If the needle doesn't move at all, you have a broken circuit.

To find the break, open the circuit by separating the splice at the firing wire end of the circuit. Test your splices individually (fig. 12-15) with the galvanometer. Remember



A. Splicing firing wires from the blasting machine
B. Opening the circuit
C. Placing one galvanometer lead to one side of splice
D. Placing one galvanometer lead to other side of splice

53.171
Figure 12-15.—Testing individual splices.

that wide scale needle movement shows a good circuit, and that no movement of the needle indicates an open.

SAFETY PRECAUTIONS APPLICABLE TO ELECTRIC FIRING SYSTEMS.—In addition to general safety measures, the following precautions must be observed when an electric firing system is set up.

1. Do not use electric blasting caps or charges in the vicinity of:

Thunderstorms
Static electricity
Transmitters of radio frequency energy
High voltage transmission lines

2. Do not pull leg wires of electric blasting caps.

3. Do not set up a firing circuit so that a strain on the leg wires or firing wires might pull the leg wires out of a blasting cap. Special care must be taken when firing wires or charges are partially unsupported or are placed in waves or currents.

4. Keep both ends of the firing wire twisted together at all times except when testing or connecting the circuit.

5. Do not take the safety shunt off an electric cap until the cap is tested. Replace the shunt after a test, and leave it on until the cap is connected into the firing circuit. If a cap does not have a shunt, twist together the bare ends of its leg wires.

6. In any multiple hookup always use electric blasting caps of same manufacture or lot number.

7. Before priming a charge to be fired electrically, observe the following steps in the order shown:

Test firing wire.
Test electric blasting caps.
Connect electric blasting caps to the circuit.
Prime charge.

8. Test firing circuit prior to connecting blasting machine.

9. After a charge is fired, disconnect the ends of the firing wire from the blasting machine and twist them together.

Firing with the Blasting Machine

When your final test shows a complete circuit, replace the handle on the blasting machine. (You've been carrying the handle in your pocket as a safety measure.) Make one final check to be sure there is nobody in the danger zone. Loosen the nuts on the blasting machine terminals, connect the ends of the firing wire, and tighten the nuts.

To fire the charge, operate the handle vigorously. The blasting machine doesn't apply its power to the circuit until the handle reaches the end of its stroke. To be sure it's moving fast when it reaches the end of its stroke, turn it with your full strength.

Firing with Other Sources of Electricity

If you use batteries to power your firing circuit, be sure they're in good condition. Use fresh dry cells, or freshly charged storage batteries. Don't depend on batteries for firing power unless you know for sure they're strong enough for the job. That's something you learn from experience.

The use of alternating current for blasting is a complicated subject, and we won't go into it here.

Electric Misfires

If the charges don't fire on your first attempt, try again. Turn the handle of the blasting machine harder, or use a bigger machine. If you're using batteries, add more batteries in series.

If the charge still won't fire, you'll have to investigate. First, if you're using batteries, disconnect them and, carry them away from the firing wire. If you're using a blasting machine disconnect it; take the handle off and put it in your pocket. Twist the ends of the firing wire together. Then you can look for the trouble.

But this applies ONLY if electric firing is the only method you're using. If you have a dual firing system, and have an electric misfire after another misfire, wait a full 30 minutes before you go near the charges.

FIRING WITH DETONATING CORD

Detonating cord may be used for firing single or multiple charges. When you detonate the cord, a wave of explosion travels down its length to the charge. You can tie branch lines onto the main cord and a wave of detonation will be transmitted to each of the branching cords. To detonate the cord, you can use either the electric or nonelectric blasting cap, or a detonating cord initiator. But don't forget that you need some delay at the firing point—time fuse with a nonelectric cap, for example (fig. 12-16). Remember this: There's NO delay in the primacord itself; the wave of detonation travels down the cord at about 4 miles a second.

Here are some more points to remember.

1. When you unwind the cord from its spool, it tends to form a spiral. Straighten it out before you connect it to the charge. If the cord loops, the detonation of one part might cut the other in two without detonating it.
2. Avoid kinks or sharp bends in the cord.
3. Don't remove any part of the fabric covering, for any reason.
4. In cold weather, the cord tends to get brittle. Handle it with extra care, to keep from cracking the fabric cover or breaking the explosive train.

Detonating Cord Connections

After you've planned your cord layout, run your main cord to its charge. Tie on branch lines leading to other charges. Let branch lines run out at a right angle to the main line, or let them run forward in the direction the detonation wave will travel. But don't let them lead back toward the cap end of the main line.

To fasten a branch line to the main line, use a GIRTH HITCH. Leave a free end at least 6 inches long, to protect the connection from moisture.

To connect two cords end-to-end, tie a square knot and pull it tight. If the knot will be under water, or if you're going to cover it with earth, make it extra tight. Don't forget to leave 6 inches of each cord free beyond the knot.

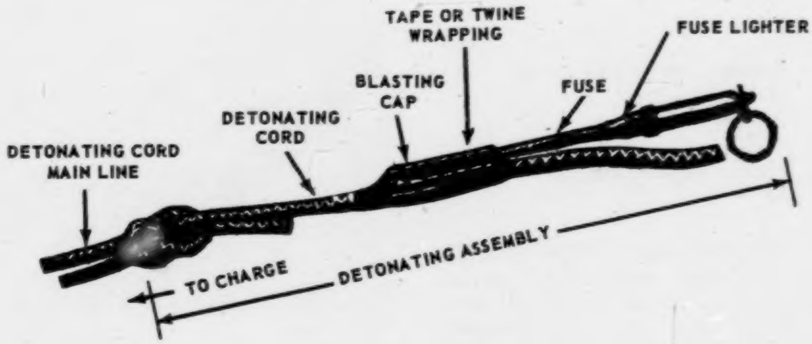
You can connect any number of branch lines to the same main line, but never more than one at any one point. (That's to keep one line from breaking another without detonating it.) And never tie on a branch line at a splice in the main line.

Firing Primacord with Blasting Caps

You can use either an electric or nonelectric cap to detonate primacord. If you use a nonelectric cap, insert the proper length of time fuse, and crimp the cap on the fuse before you attach the cap to the primacord. Hold the cap parallel to and against the cord, with its CLOSED end pointing toward the charge. (See fig. 12-16.) Leave at least 6 inches of cord free at the other end of the cap. Tape or tie the cap firmly in place against the cord.

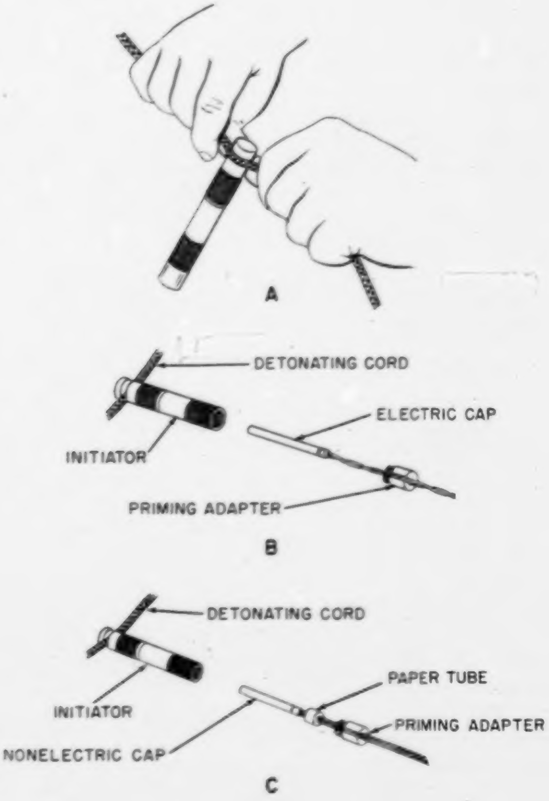
Then fire the cap in the same way (and with the same precautions) you would use if it were attached to the main charge.

You can also fire primacord by using a cap and the intiator as in figure 12-17. As you can see, the setup is about the same whether you are using the electric or nonelectric cap. The paper tube which comes in the initiator is discarded when the electric cap is used.



53.172

Figure 12-16.—Initiating detonating cord with time fuse and nonelectric blasting cap.



A. Forcing initiator onto detonating cord
B. Assembling initiator to electric cap
C. Assembling initiator to nonelectric cap

53.173
Figure 12-17. — Using the detonating cord initiator.

Priming TNT and Plastic Explosives With Detonating Cord

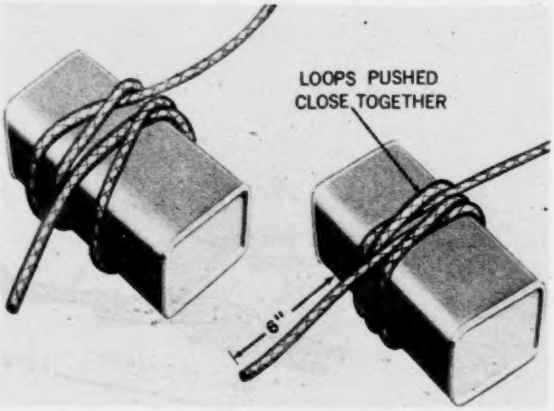
When priming adapters are available, TNT blocks containing threaded cap wells can be primed with detonating cord to which a nonelectric cap has been attached. When priming adapters are not available, or when the TNT blocks do not contain threaded cap wells, the blocks can be primed by tying detonating cord in a clove hitch around the explosive charge (fig. 12-18).

In priming plastic explosives (compositions C3 and C4) with detonating cord, proceed as follows. Refer to figure 12-19.

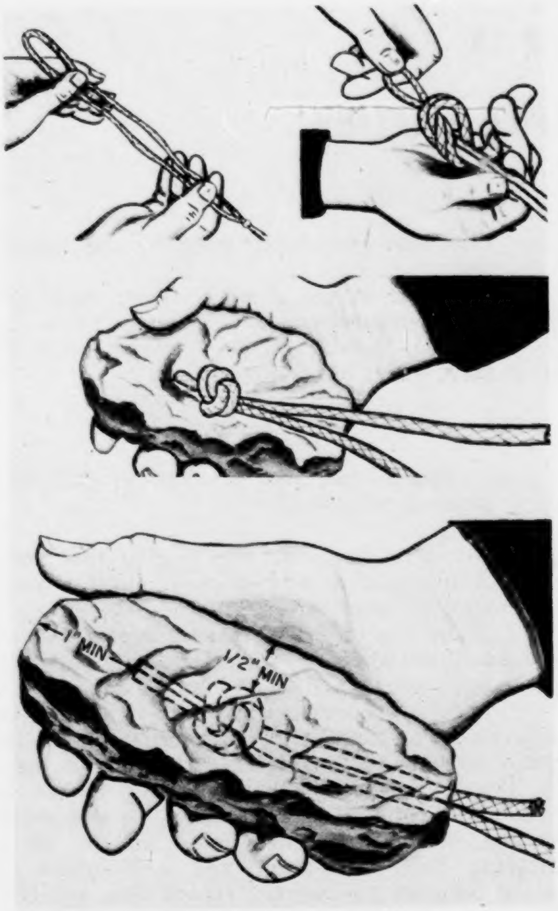
1. Take a 10-inch bight at the end of the detonating cord and tie an overhand knot in it.
2. Mold the explosive around the knot, with at least 1/2 inch of explosive on all sides and at least 1 inch on each end.

ORDNANCE SAFETY PRECAUTIONS

The results of accidents involving naval ordnance are too well known to require detailed discussion. The best interests of the Navy and of each individual in an ordnance rating are best served when there is an effective body of ordnance safety precautions, and all personnel involved with ordnance have been well instructed in these precautions. All enlisted personnel having ordnance type ratings and strikers for such ratings must have complete knowledge of the general and specific ordnance safety precautions and safety principles. OP 3347, United States Navy Ordnance Safety Precautions, lists specific safety precautions which apply specifically to explosive and nonexplosive ordnance material and equipment located both ashore and afloat.



53.175
Figure 12-18.— Priming TNT block with primacord.



53.176
Figure 12-19.—Priming plastic explosive with detonating cord.

All personnel in ordnance ratings shall remain alert at all times to ensure through compliance with and enforcement of ordnance safety precautions. Personnel required to handle ammunition shall be carefully and frequently instructed in the safety precautions, methods of handling, storage and the use of all kinds of ammunition and explosive ordnance which the vessel or station may be supplied. No one shall be permitted to inspect, prepare, or adjust live ammunition and explosives until he thoroughly understands his duties, the precautions, and the hazards involved. All persons who supervise work in connection with the inspection, care, preparation, use, or handling of ammunition or explosives shall:

1. Exercise the utmost care that all regulations and instructions are observed.

2. Carefully instruct those under them and frequently warn them of the necessity of using the utmost care in the performance of their work. No relaxation of vigilance shall be permitted.

3. Explain to their subordinates the characteristics of the ammunition, explosives, and other dangerous materials; the equipment, the precautions to be observed; and the hazards of fire, explosion and other catastrophies which the safety precautions are intended to prevent.

PEACETIME SAFETY RULES

The need for extreme caution in peacetime operations with nuclear weapons is obvious. Safety rules were developed by all services for every nuclear weapon system. These rules are to be used in peacetime and wartime, when possible. All safety rules are applied against the four safety standards, which are as follows:

Positive measures will be taken to prevent weapons involved in accidents or incidents, or jettisoned weapons, from producing a nuclear yield.

Positive measures will be taken to prevent deliberate arming, launching, firing, or releasing except upon lawful orders.

Positive measures will be taken to prevent inadvertent arming, launching, firing, or releasing.

Positive measures will be taken to ensure adequate security.

CHAPTER 13

ADMINISTRATIVE DUTIES

Now that you're advancing to First Class or Chief, you can expect more administrative duties than you've had in the past. For example, there are inspections, tests, and checks to be made on equipment, logs and records to be kept, inventories to be taken, spare parts to be ordered, training schedules to be drawn up, reports to be made, and various other "paper work" jobs to perform. These duties will be as much a part of your job as is supervising the men in your division. As you can see, increasing responsibility goes along with that third stripe—or the "hat."

REPORTS

Reports are required by Naval Ordnance Systems Command (NAVORDSYSCOM), type commanders, and other interested commands or offices to keep informed of the status of ordnance equipment and whether it is functioning efficiently. Most of these reports will be made by the weapons officer, or his administrative assistant; however, much of the information required must be supplied by the leading petty officers of the department.

All reports currently required by OPNAV and NAVORDSYSCOM directives are listed in the latest revision of OPNAVINST 5214.1C (Consolidated List of Recurring Reports Required by the Bureaus and Offices, Navy Department, from the Operating Forces of the Navy). This listing does not include reports required by fleet, force, and type commanders. Reports required by the bureaus or commands from shore activities are listed in AO (Administrative Office) INST 5213.2. NAVORDSYSCOM lists all reports required by its office from all activities, ashore or afloat, under the report control in the latest revision of NAVORD INST 5213.3.

Each of these listings gives the report symbol, title, form or format, frequency, requiring directive, requiring office code letters, and the activities who must prepare and submit the report.

In addition to the above listings, each type commander issues an instruction, also in the 5213 series, listing all the reports required from ships under his command.

TYPES OF REPORTS

All reports fall into one of the following three general categories:

1. Periodic reports, which give the same type of information at regular intervals—such as monthly or quarterly.
2. Situation, or performance, reports which are submitted whenever the action being reported on occurs, such as loss of small arms report.
3. Special reports, which are a one-time report such as a report of inventory of a specific class or type of material or equipment held by the activities of the operating forces at a specific time. These reports are requested by the bureau, systems command or office desiring the information, and instructions as to the form of the report, report date, symbol, etc., usually are set forth in the form of a speedletter and distributed to all activities concerned.

In any case, the requiring directive for each report normally will give you the instructions for preparing and submitting the report. Type commander's competition manuals will tell you how to make competitive exercise reports. These reports are the weapons officer's responsibility, of course, but possibly you could be called upon for some assistance in drafting such reports. The type commander may also issue "Gunnery Notes" and "Administrative Manuals" which give further information on reporting procedures.

In the following paragraphs, the Gun Wear/Star Gauge Report will be briefly described as examples of periodic and situation reports respectively.

GUN WEAR/STAR GAUGE REPORT

In compliance with NAVORD INST 8300.3, all ships and stations having 3'' to 16'' naval guns are required to submit a Gun Wear/Star Gauge Report on NAVORD Form 8300/3 at least annually on approximately 1 May. NAVORD Form 8300/3 (fig. 13-1), is a single form which replaces both NAVORD Form 54, Star Gauge Report, and NAVORD Form 2124, Gun Wear Report, which were formerly used to report the wear status of naval guns.

As star gauges normally are not carried aboard most ships, star gauging should be requested from a tender, or other available facility, as near to the report date of 1 May as is feasible. Bore erosion gauge readings should be taken by ship's company personnel on the same date that star gauge readings are taken. Precautions in taking both types of readings and complete instructions for preparing and submitting NAVORD Form 8300/3 are included in NAVORDINST 8300.3.

The original of this report is submitted to the Commanding Officer, Naval Ordnance Station, Central Technical Documents Office (Code V-2), Louisville, Kentucky 40214; one copy to Commander, Naval Weapons Laboratory, Dahlgren, Virginia 22448; one copy to appropriate type commander; unless otherwise directed; and one copy is retained on board for file. The readings obtained for this report should also be submitted to your ship's fire control officer for the purpose of determining velocity loss correction for the battery.

When the Bore Erosion Gauge Reading, Enlargement at the Origin of the Bore, or other criteria as listed in Chapter 3 of OP 1549, Service Life of U.S. Naval Gun Barrels, indicates that barrels are eighty percent expended, regunning shall be requested from NAVORDSYSCOM via the type commander.

FORMS

Forms are any printed labels or tags, placards, signs, decals, drawing formats, form letters, and any other duplicated or printed papers which require clerical fill-ins or have blank spaces for the insertion of information to complete their meaning. There are different forms for different purposes. Those most commonly used are requisitions for spare parts, forms used as records, and forms used for reporting on ordnance material. It is the policy of the Naval Ordnance Systems Command to keep the required number of forms to a minimum. Forms should be used only to the extent that they serve their intended purpose. If you find that a form has insufficient space for your purpose, put the needed information in a letter and send it along with the form.

DISTRIBUTION OF FORMS

You can find full information on the distribution of forms, and instructions for requisitioning them, in NAVSANDA 2002. This publication lists all NAVORD forms used by both fleet and shore activities.

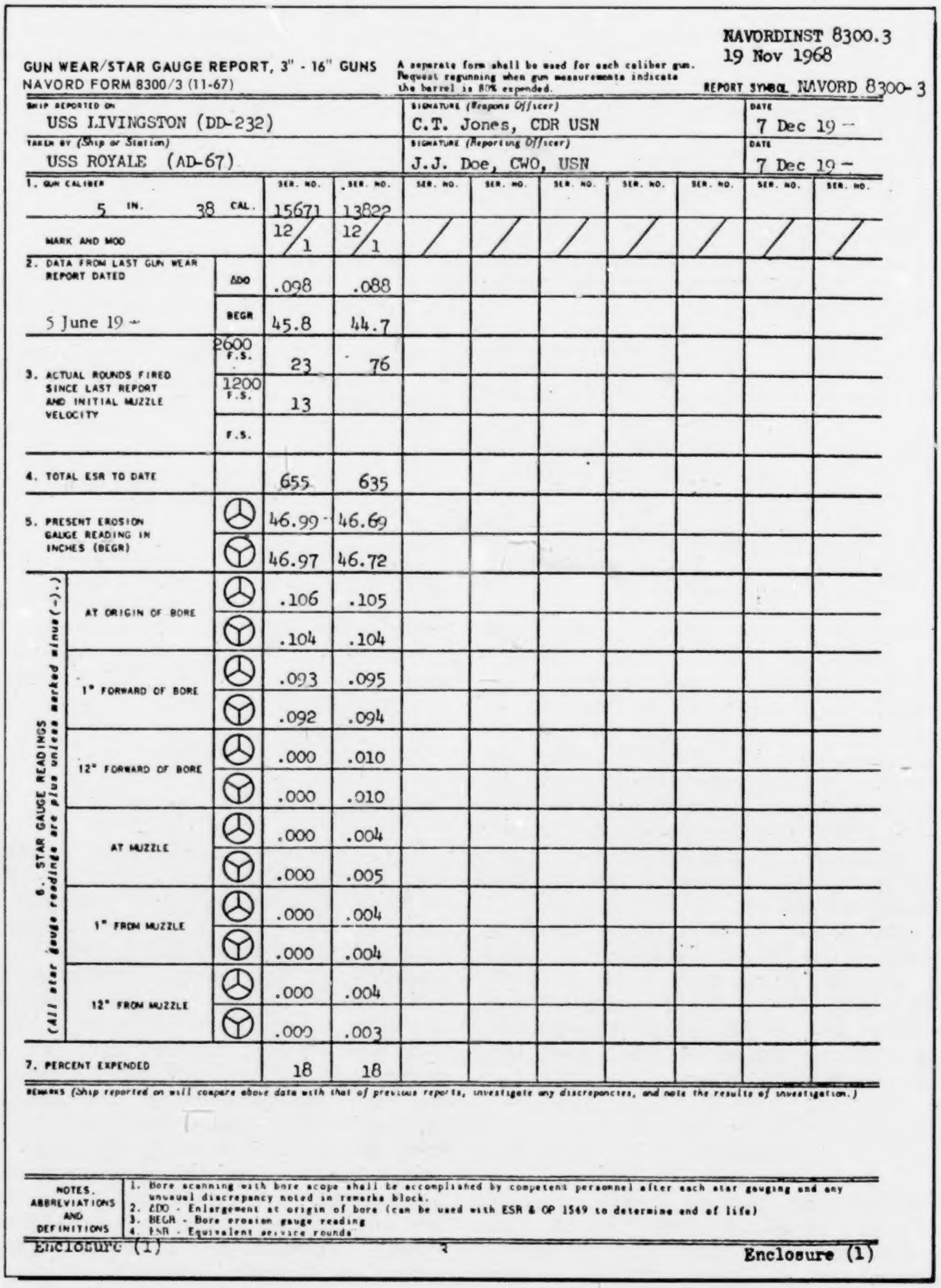
SHIPBOARD GUNNERY LOGS AND RECORDS

The following material is intended as a guide for setting up and maintaining the required gunnery logs and records. It includes instructions concerning allowance lists, the ordnance inventory, and the required reports. Because these logs and records are standardized throughout the fleet, you won't have to learn new record-keeping methods each time you are transferred from one duty station to another.

ALLOWANCE LISTS

An allowance list is simply a list of items that a ship is supposed to carry. When a ship is placed in commission, or when new ordnance material is issued to a ship already in commission, an allowance list is prepared by NAVORDSYSCOM and issued to the ship. Allowance lists cover ammunition, the main units and subunits of equipment such as guns, mounts, and fire control instruments, and the spare parts, accessories, and special tools required for the maintenance of this material. The allowance lists identify each item by its name, description, and drawing and stock numbers, and tell how many items of each kind are to be carried. Articles listed on the allowance, but not on board, may be requisitioned from supply activities or, in certain cases, from repair ships or other vessels.

Proper maintenance of allowance lists, and periodic inventory of equipments, spares, and



NAVORDINST 8300.3
19 Nov 1968

GUN WEAR/STAR GAUGE REPORT, 3" - 16" GUNS
NAVORD FORM 8300/3 (11-67)

A separate form shall be used for each caliber gun. Request regunning when gun measurements indicate the barrel is 80% expended.

REPORT SYMBOL NAVORD 8300-3

SHIP REPORTED ON: USS LIVINGSTON (DD-232)
SIGNATURE (Weapons Officer): C.T. Jones, CDR USN
DATE: 7 Dec 19 -
TAKEN BY (Ship or Station): USS ROYALE (AD-67)
SIGNATURE (Reporting Officer): J.J. Doe, CWO, USN
DATE: 7 Dec 19 -

1. GUN CALIBER	5 IN. 38 CAL.		SER. NO. 15671	SER. NO. 13822	SER. NO.	SER. NO.	SER. NO.	SER. NO.	SER. NO.	SER. NO.	SER. NO.
MARK AND MOD			12/1	12/1	/	/	/	/	/	/	/
2. DATA FROM LAST GUN WEAR REPORT DATED		ΔDO	.098	.088							
5 June 19 -		BEGR	45.8	44.7							
3. ACTUAL ROUNDS FIRED SINCE LAST REPORT AND INITIAL MUZZLE VELOCITY		2600 F.S.	23	76							
		1200 F.S.	13								
		F.S.									
4. TOTAL ESR TO DATE			655	635							
5. PRESENT EROSION GAUGE READING IN INCHES (BEGR)		⅄	46.99	46.69							
		Y	46.97	46.72							
6. STAR GAUGE READINGS (All star gauge readings are plus unless marked minus (-).)	AT ORIGIN OF BORE	⅄	.106	.105							
		Y	.104	.104							
	1" FORWARD OF BORE	⅄	.093	.095							
		Y	.092	.094							
	12" FORWARD OF BORE	⅄	.000	.010							
		Y	.000	.010							
	AT MUZZLE	⅄	.000	.004							
		Y	.000	.005							
	1" FROM MUZZLE	⅄	.000	.004							
		Y	.000	.004							
	12" FROM MUZZLE	⅄	.000	.004							
		Y	.000	.003							
7. PERCENT EXPENDED			18	18							

REMARKS (Ship reported on will compare above data with that of previous reports, investigate any discrepancies, and note the results of investigation.)

NOTES, ABBREVIATIONS AND DEFINITIONS

1. Bore scanning with bore scope shall be accomplished by competent personnel after each star gauging and any unusual discrepancy noted in remarks block.
2. ΔDO - Enlargement at origin of bore (can be used with ESR & OP 1549 to determine end of life)
3. BEGR - Bore erosion gauge reading
4. ESR - Equivalent service rounds

Enclosure (1)

Enclosure (1)

53.255

Figure 13-1.—Sample-Gun Wear/Star Gauge Report.

accessories are necessary to ensure that all authorized ordnance equipment is on board or on order. When experience indicates deficiencies or excesses in an allowance list, ships and other operating commands should recommend changes to NAVORDSYSCOM via the type commanders. Recommendations from the fleet are a valuable source of information for NAVORDSYSCOM.

Allowance lists are also published by other Navy bureaus and systems commands for equipment under their cognizance. Separate lists, for example, have been established by NAVORDSYSCOM to cover various kinds of equipment such as electrical, electronic, hull, and machinery.

COSAL

The Coordinated Shipboard Allowance List (COSAL) eventually will supersede virtually all individual allowance lists currently in use. The only material not included in COSAL will be: medical material, hydrographic charts, ship's store merchandise, lubricants, and ammunition.

The COSAL is explained and illustrated in Military Requirements for Petty Officer 3 & 2, NavPers 10056. As a GM in the weapons department, the parts of the COSAL that will concern you are the sections that list the weapons systems and the tools and repair parts allowed for their maintenance. The type and quantity of repair parts alloted a ship was determined by studies of requirements in the past. Each ship has a COSAL prepared just for it, and the ship is stocked accordingly.

The ordnance section of the COSAL is made up of three separate parts. The Introduction to the COSAL gives complete information on the use of the COSAL; study this part carefully before using the COSAL. The stock numbers given in COSAL listings are Federal Stock Numbers (FSNs), except when a piece of equipment is so new that its repair parts have not fully been incorporated into the Navy supply system. These parts are listed by manufacturer's part numbers. The Federal Supply Classification system and the numbering system were explained in Military Requirements for Petty Officer 3 & 2; review it if you have forgotten.

The ordnance segment of the COSAL is an allowance list of ordnance equipment/equipage, supporting repair parts, and other materials tailored to the individual ship. As each active ship with ordnance installations undergoes overhaul, it is supplied with a new ordnance segment of the COSAL. All active fleet, new construction, and major conversion ships with installed armament receive an ordnance segment of the COSAL.

How To Use the COSAL

Again we'll say, study the Introduction to the COSAL carefully before using any other part of it.

Part I of the COSAL lists your equipment, and major equipment components and equipage, and gives the allowance parts list (APL) numbers, and allowance equipage list (AEL) numbers. These identification numbers act as page numbers for a more complete breakdown of the components in Part II.

Part II is the Allowance Parts List of repair parts needed to support the items in Part I. Each Allowance Parts List (APL) gives the complete nameplate data for the equipment and lists the repair parts for this equipment.

Part III of the COSAL gives the final authorized on-board allowance quantity of a repair part, and it will tell you if the part you require is on board in supply department storerooms. It is here that the total allowance of parts which may be common not only to the ordnance section of the COSAL but other departments as well are added together. That is, your section of the COSAL may permit you an allowance of three particular limit switches. The engineers' COSAL may show their allowance to be six of the same switches. Part III of the COSAL will show a total of nine of these switches, giving their applications.

Records and Reports For COSAL

The COSAL for each ship is prepared by the Ship's Parts Control Center (SPCC), Mechanicsburg, Penna., which also stocks the ship with the listed equipments and repair parts, either at outfitting of a new or a converted ship, or just before overhaul. Minor revisions to the COSAL are made as pen-and-ink changes on the ship's copy. More extensive revisions or additions are distributed as changes.

The COSAL does not generate any additional reports or records but simplifies your recordkeeping. It gives you the Federal Stock Number for most of the items you have to order, and thus saves much looking up of those numbers. It also lists the items your ship is allotted, so you will not unknowingly attempt to order something that is not allowable.

ORDNANCE INVENTORIES

Inventories of ordnance equipment are required at various times, and for various reasons. They may be ordered by the commanding officer or department head; or they may be required by a NAVORDSYSCOM or NAVSUPSYSCOM directive. Inventories of equipage are required upon relief of a department head when the responsibility for ordnance equipage changes hands, or when a ship goes into the COSAL system of supply.

One of the most comprehensive inventories you will be likely to take will be the checking, and correcting as necessary, of the Ship Armament Inventory List (SAIL). We will discuss SAIL later in this chapter.

All inventories are important, and they must be carefully prepared. Inventory reports to NAVORDSYSCOM or NAVSUPSYSCOM, for example, are the basis for allocating funds for alterations, for providing an adequate supply of repair parts for your guns, and for miscellaneous inventory control functions.

SHIP ARMAMENT INVENTORY LIST

The Ship Armament Inventory List (SAIL) is a reporting system which furnishes NAVORD and all commands concerned with a master armament configuration listing of installed shipboard nonexpandable ordnance equipment together with pertinent Ordnance Alterations (ORDALTS) status. SAIL is produced on data processing equipment and includes the ordnance equipment listed in the Ordnance Systems Patterns portion of Index of Alterations to Ordnance Equipment (ORDALT OO). The SAIL program supersedes the formerly used Ordnance Inventory/Ordalt Status Listing, which it greatly resembles.

Each ship has on board two copies of SAIL supplied by NAVORDSYSCOM. A sample copy of SAIL is shown in figure 13-2. Prior to a scheduled overhaul availability, this list should be reviewed and all changes in armament and ORDALT completion status that have taken place since the last printing of the listing should be annotated on one copy of the list. This corrected copy should be marked "PRIOR TO OVERHAUL REPORT" and submitted to reach NAVORDSYSCOM (ORD 041B3) on the first of that month 7 months prior to a scheduled yard overhaul. After submitting these corrections, NO corrections to the SAIL should be forwarded until completion of the yard availability. Complete instructions for correctly annotating SAIL can be found in NAVORD INST 8000.1.

SAIL Distribution.

a. The Naval Ordnance Systems Command normally will distribute copies of SAIL to:

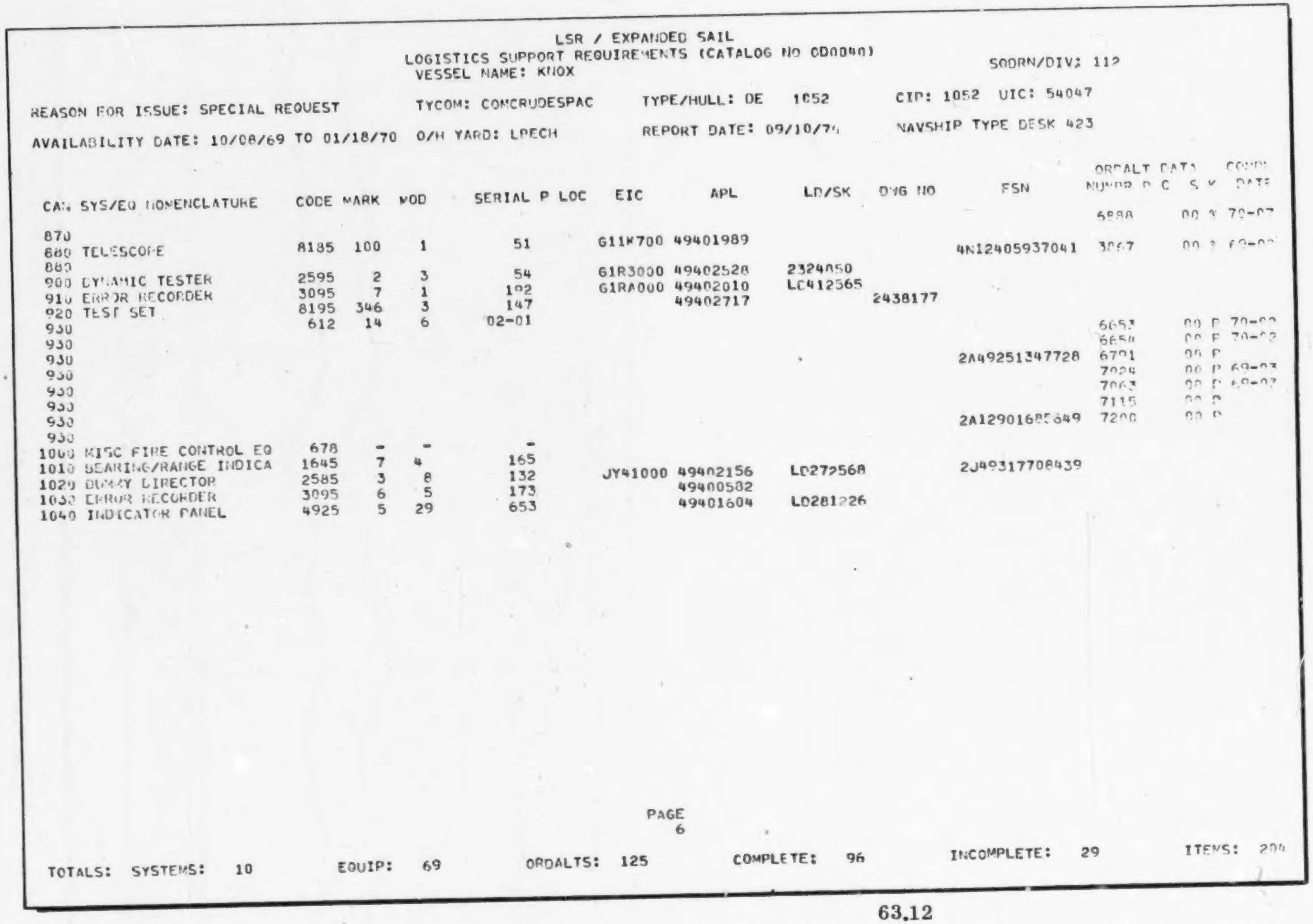
Naval Shipyard/SUPSHIPS/INDMAN (as appropriate)
Ship/Station/Command
ESO
SPCC
NAVWPNSERVO
Type commander
NAVPLANTREP
NSMSES (SMS ships only)
NUWRES (ASW ships only)

b. The SAILS distribution schedule will be as follows:

EVENT	
Construction/ Conversion	12 months prior end-of construction/conversion End of conversion/fitting-out
Regular Overhaul (ROH)	6 months prior to commencement 2 months after completion
Post Shakedown Availability (PSA)	2 months after completion
Significant Change	2 months after receipt of report

Within 10 days following completion of shipyard overhaul, the ship shall annotate the SAIL to indicate all corrections, additions, and deletions, mark the report "OVERHAUL COMPLETION REPORT", and forward one copy to NAVORDSYSCOM. Upon receipt of this verified and corrected copy, NAVORDSYSCOM processes the corrections, and a new revised SAIL is distributed as indicated above.

Any changes in reportable ordnance equipment installed aboard, or the accomplishment of an ORDALT which takes place at times other than as specified above, should be reported when



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                                        LSR / EXPANDED SAIL
                              LOGISTICS SUPPORT REQUIREMENTS (CATALOG NO OD0040)
                               VESSEL NAME: KNOX                                         SODRN/DIV: 112

REASON FOR ISSUE: SPECIAL REQUEST      TYCOM: COMCRUDESPAC     TYPE/HULL: DE   1052      CIP: 1052  UIC: 54047

AVAILABILITY DATE: 10/08/69 TO 01/18/70  O/H YARD: LPECH       REPORT DATE: 09/10/74     NAVSHIP TYPE DESK 423

                                                                                                      ORDALT DATA    COMPL
 CAN SYS/EQ NOMENCLATURE    CODE MARK  MOD     SERIAL P LOC  EIC      APL        LD/SK   DWG NO       FSN         NUMBR P C  S K  DATE
                                                                                                      6888       00 X 70-07
 870
 880 TELESCOPE              8185  100    1          51     G11K700 49401989                      4N12405937041  3867       00 X 69-09
 880
 900 DYNAMIC TESTER         2595    2    3          54     G1R3000 49402528   2324050
 910 ERROR RECORDER         3095    7    1         192     G1RA000 49402010   LC412565
 920 TEST SET               8195  346    3         147             49402717           2438177
 930                         612   14    6       02-01
 930                                                                                                  6653       00 P 70-02
 930                                                                                                  6654       00 P 70-02
 930                                                                                 2A49251347728    6791       00 P
 930                                                                                                  7024       00 P 69-03
 930                                                                                                  7063       00 P 69-07
 930                                                                                                  7115       00 P
 930                                                                                 2A12901685649    7200       00 P
1000 MISC FIRE CONTROL EQ    678    -    -           -
1010 BEARING/RANGE INDICA   1645    7   4          165
1020 DUMMY DIRECTOR         2585    3    8         132     JY41000 49402156   LD272568               2J49317708439
1030 ERROR RECORDER         3095    6    5         173             49400582
1040 INDICATOR PANEL        4925    5   29         653             49401604   LD281226

                                                        PAGE
                                                         6

 TOTALS:  SYSTEMS:   10        EQUIP:   69       ORDALTS:  125       COMPLETE:   96       INCOMPLETE:   29        ITEMS:  204
```

63.12

Figure 13-2.—Ship Armament Inventory List (SAIL).

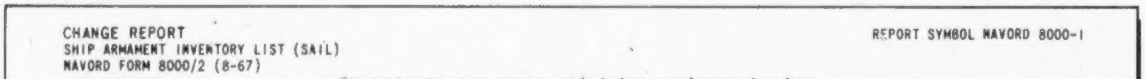
occurring using Ship Armament Inventory List (SAIL) Change Report, NAVORD Form 8000/2 figure 13-3. This report is required because NOSC NAVORDSYSCOM must have, at all times, an up-to-date listing of inventory and ORDALT status for each ship. No revised SAILS are produced, except as provided above, unless NAVORDSYSCOM considers that the changes are of such significance as to render the latest SAIL obsolete.

For purposes of current reference, ships and activities should keep their latest copy of SAIL marked up to date and destroy the previous one.

OAR PROGRAM

The ORDALT Accomplishment Requirement (OAR) is a list issued by NAVORDSYSCOM on NAVORD Form 8000/16 (figure 13-4) about 6 months prior to overhaul of a ship. It lists all outstanding ORDALTS for the ship in order of priority of accomplishment and shows the estimated man-hours for accomplishment of each ORDALT, and the total estimated cost for the ship. The ship receives one copy, which must be given a thorough review and a report then submitted within two weeks to NAVORD NAVSUP the overhauling activity, and SPCC. This report must list all the ORDALTS completed after the "Prior to Overhaul" SAIL was submitted, all ORDALTS that should be on the OAR list but are not, all ORDALTS that are on the OAR list but are not applicable, and a list of all applicable ORDALT material on board. Upon receipt of this report, the appropriate offices will amend the OAR, requisition material, and plan to accomplish as much of the required ORDALT work as is possible within the limitations of time and available funds.

Within ten days after completion of overhaul, the shipyard, or overhauling activity, submits a report to NAVORD and NAVSUP of the ORDALTS they have accomplished and the total



CHANGE REPORT
SHIP ARMAMENT INVENTORY LIST (SAIL)
NAVORD FORM 8000/2 (8-67)
0105 380 0120

REPORT SYMBOL NAVORD 8000-1

See instructions on reverse side before completing this form.

SHIP AND HULL NO. OR SHORE ACTIVITY SNDL CODE
USS NEVERSAIL (DDG 8000)

NOMENCLATURE	MK	MOD	SERIAL	ORDALT	STATUS		DELETE	ADD	CHANGE	ACN REFERENCE
					COMPLETE	NOT COMPLETE				
Indicator Panel	5	10	653	4188	✓					510

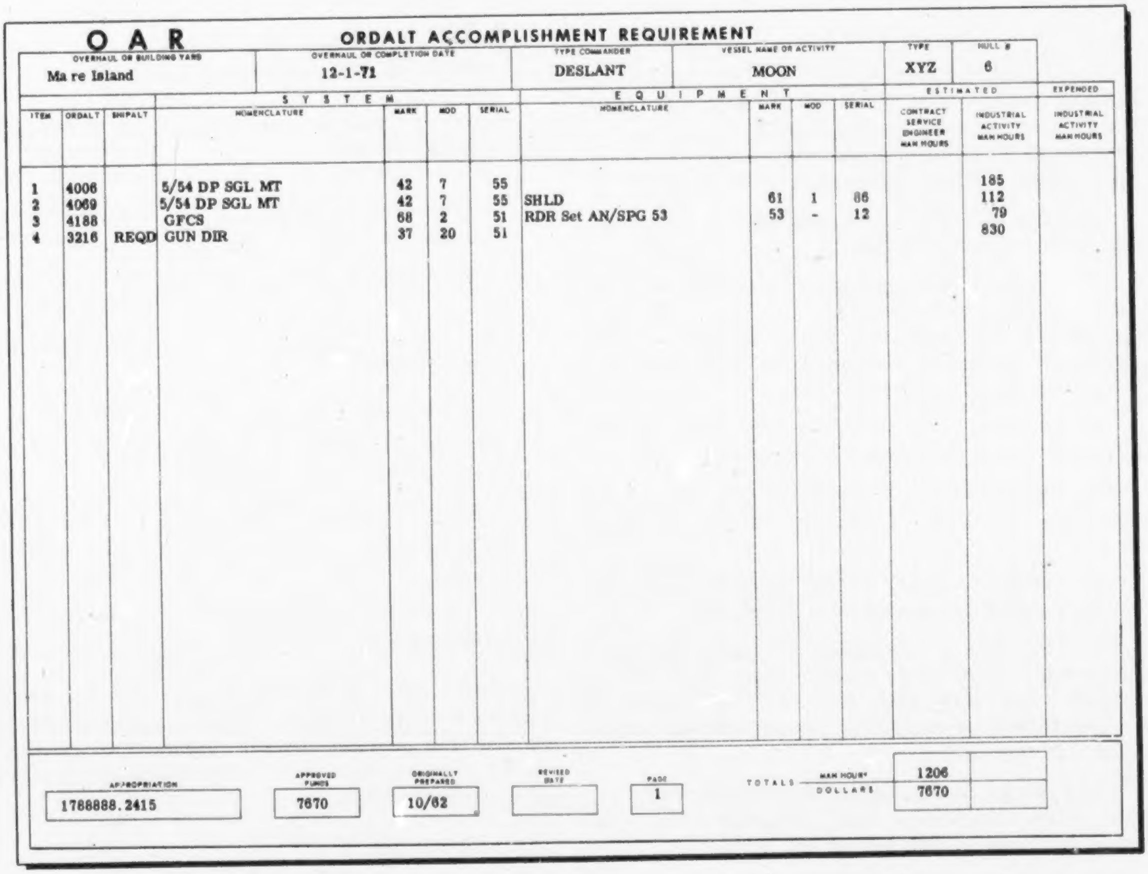
The above changes to Ship Armament Inventory List have been properly recorded on equipment nameplates and ORDALT plates and on Ordnance History Cards.

SIGNATURE AND RANK OF REPORTING OFFICER
V.G. Flynn Lt. (USN)

DATE REPORT SUBMITTED
11-5-71

180.121

Figure 13-3.—SAIL Change Report, NAVORD Form 8000/2.



O A R **ORDALT ACCOMPLISHMENT REQUIREMENT**

OVERHAUL OR BUILDING YARD	OVERHAUL OR COMPLETION DATE	TYPE COMMANDER	VESSEL NAME OR ACTIVITY	TYPE	HULL #
Ma re Island	12-1-71	DESLANT	MOON	XYZ	6

			SYSTEM				EQUIPMENT				ESTIMATED		EXPENDED
ITEM	ORDALT	SHIPALT	NOMENCLATURE	MARK	MOD	SERIAL	NOMENCLATURE	MARK	MOD	SERIAL	CONTRACT SERVICE ENGINEER MAN HOURS	INDUSTRIAL ACTIVITY MAN HOURS	INDUSTRIAL ACTIVITY MAN HOURS
1	4006		5/54 DP SGL MT	42	7	55						185	
2	4069		5/54 DP SGL MT	42	7	55	SHLD	61	1	86		112	
3	4188		GFCS	68	2	51	RDR Set AN/SPG 53	53	-	12		79	
4	3216	REQD	GUN DIR	37	20	51						830	

APPROPRIATION	APPROVED FUNDS	ORIGINALLY PREPARED	REVISED DATE	PAGE
1788888.2415	7670	10/62		1

TOTALS		
MAN HOURS	1206	
DOLLARS	7670	

63.13

Figure 13-4.—ORDALT Accomplishment Requirement (OAR).

cost. A revised SAIL, reflecting this report and the ship's annotated SAIL "OVERHAUL COMPLETION REPORT", is then issued by NAVORD and sent to the ship.

Further details on OAR can be found in NAVORD INST 8000.5 (current as of this writing).

LOGS

A log is a book in which you keep a record of tests, overhauls, repairs, alterations, maintenance, etc. You can make longhand entries in a stitched type notebook, or typewritten entries in a looseleaf book. If your log entries are prompt and accurate, they will later help you to discover both faulty design and faulty maintenance procedures. The 3-M system, where implemented, has replaced some, but not all, of the logs discussed in this chapter. On some ships all of the logs are still in use and are required by many local commanders.

Of the various logs you will use, two of the most important are Battery Logs and Fire Control Logs. Among the things you will enter in these logs are data on:

1. Drills and exercises.

2. Execution of routine, prefiring, and postfiring checkoff lists.

3. Unspecified lubricants used, and the reasons for using them.

4. Performance and results of tests, checks, and measurements.

5. Special inspections.

6. Maintenance procedures not covered by checkoff lists, such as adding hydraulic fluid (state quantity and type); filling, flushing, or draining of hydraulic units; tightening bolts and nuts; adjustments; boresighting; star-gauging.

7. Adverse effects of weather on material, maintenance, or operation.

8. Detailed description of casulties — giving name, mark, mod, serial number, and part number of the unit and parts involved; what happened; probable cause; how repaired; and steps taken to prevent recurrence.

9. Repairs. Tell why repairs were necessary, and which parts were replaced.

10. Modifications. Record the number of the pertinent ORDALT, SHIPALT, Field Change, etc.

11. Tram readings, roller path compensator settings, and erosion indicator readings.

12. List of major units or subassemblies of mounts, including mark, mod, and serial number. Put this list in the first pages of the log. It will be useful for proper identification of units of equipment.

13. Firings, including number of rounds fired, type, date, occasion, and Equivalent Service Round, all kept by gun serial number.

14. Daily test of cease-firing gongs, buzzers, and lights.

Following are brief descriptions of the various special logs that must be maintained.

Battery Logs

As a minimum requirement, battery logs are to be maintained for:

Turret Logs	1 per terret
5'' Mount	1 per mount
3'' R-F Mount	1 per mount
3' Slow Fire Mount	1 per battery
40-mm Mount	1 per battery
20-mm Mount	1 per battery
Torpedo Battery	1 per battery
A/S Launchers	1 per type of launcher
Rocket Launcher	1 per battery

Fire Control Logs

As a minimum requirement, fire control logs are to be maintained for:

Computer and/or Rangekeeper	1 per computer or range-keeper
Fire Control System Logs	1 per type of system
Stable Elements	1 per stable element
Target Designation Equipment	1 per system
Gunsight Log	1 per ship
Rangefinder and Optic Logs	1 per ship
Battery Alignment Logs	1 per battery
Fire Control Radar Log	1 per equipment

Small Arms Log

The small arms log should list the serial numbers of the small arms on board, and entries in the log should include casualties, repairs, modifications, results of inventories, and location of normal stowage.

Ballistics Logs

The ballistics log should be maintained to show gun ballistic variables. A separate log should be kept for each gun battery. A record is made of the rounds fired by each gun, the star gauge data, and bore erosion data. This data should be recorded for each gun by serial number of the gun barrel. This log forms the basis for computation of Equivalent Service Rounds (ESR). It can also be used to record any data affecting the ballistics of any particular gun in the battery. Don't record such routine items as cleaning and ship's drills. On days when no items of interest occur, just enter the date and your initials.

As we said earlier in this chapter, certain information should be periodically transferred from the logs to the Ordnance History. We can't specify each kind of entry that should be transferred. But be sure to enter information on casualties, repairs, alterations, field changes, modifications, and repeated failures.

Magazine Temperature Log

The magazine temperature log is a day-to-day record of magazine temperatures and magazine sprinkling system tests. Make the daily entries for this record on a card posted in the magazine in a conspicuous place near the thermometer. The card is kept on a monthly basis. It has spaces for recording the maximum and minimum temperature on each day of the month, and for the initials of the person recording the temperatures. At the bottom of the card are spaces for each week of the month, in which the results of the magazine sprinkling system test are recorded and initialed by the person conducting the test. Monthly, on completion of the magazine card, the temperatures must be transcribed into a permanent log. When temperatures exceed 100° F, the recordings should be transcribed to the notebook in red ink, or made conspicuous by some other means.

Use a separate section of the magazine temperature log for recording the results of sprinkling system tests. In addition to the daily entries on the magazine card, keep a separate notebook for hourly entries of temperatures over 110° F. When such temperatures occur, the record should be transferred daily to a permanent log. Record the hourly temperatures in excess of 110° F, and a daily cumulative total of hours within each temperature range.

AMMUNITION LEDGER

The ammunition ledger is a ring type binder containing an ammunition stock record card for each type of ammunition aboard ship. There are several types of record cards now used in the fleet, NAVORD form 8015/1, NAVSUP 1298 and NAVSUP 1299. Data describing the article itself, ammunition lot numbers, FSN stock numbers and the magazine stowage area plus a record of receipts, expenditures and quantity on hand are recorded on these cards. NAVORDINST 8015.1 and NAVSUP publication 460 contain information on the use of these cards.

AMMUNITION REPORT

A quarterly ammunition report is made to the Ship's Parts Control Center (SPCC), Mechanicsburg, Pennsylvania, so that an accurate inventory of assets and expenditures of expendable ordnance items throughout the naval service can be maintained. Complete instructions concerning this report are contained in OSO Field Instructions 8015.15 and 8015.16.

Recurring Ammunition Reports

Each ship sends in an initial report on ammunition, including both service and training ammunition. This report lists the amount on hand on the cutoff date of the report and expenditures from the beginning of the fiscal year to the cutoff date. The report also includes a column for the remaining unexpended allowance of training ammunition.

Currently, COMSERVLANT INSTRUCTION 8015.1C includes the reporting instructions for this initial report and subsequent periodic reports for ships in the Atlantic area, while COMSERVPAC INSTRUCTION 8015.5 does the same for ships in the Pacific area. Type commanders may also require reports at specified intervals or times on the status of certain types of ammunition. The format and instructions for making such reports normally will be included in the notice or instruction which sets up the requirement.

REQUISITIONING OF AMMUNITION

The term "ammunition" as used here refers to all ammunition, ammunition components, other explosive devices, and pyrotechnics. DD Form 1348, a six part, 80-column, single line item document, shall be used for requisitioning ammunition, unless naval message, telephone, or radio media is used. By single line item, it is meant that but one federal stock number, Navy ammunition logistics code number, or other single item identifier shall be used on each DD Form 1348 requisition.

REQUISITIONING AMMUNITION WITH DD FORM 1348

DD Form 1348 is the basic request document utilized within the MILSTRIP system. The Military Standard Requisitioning and Issue Procedure (MILSTRIP) was developed by the Department of Defense to provide a common supply language and more effective supply system operations within the military establishment. This system standardizes forms, formats, codes, procedures, and priority systems.

Depending upon the policy followed on your particular ship, ammunition requisitions may be either handled through the ship's supply department, or sent out directly from the weapons department. As a First Class or Chief Gunner's Mate, you should be familiar enough with the MILSTRIP system to be able to correctly requisition or turn in ammunition using the proper forms and format, and to understand supply status reports on material ordered.

The following is an explanation of DD Form 1348 with brief instructions as to filling it out. As you study this part, refer to the sample form in figure 13-5 to locate the blocks being explained:

Block A — Enter the unit identifier code number, name, and address of the activity to which the requisition is to be forwarded, e.g., (671) NWS SEAL BEACH, CALIF. Unit identifier codes of naval activities are listed in NAVCOMPT MANUAL, Vol. 2 Chap. 5.

Block B — Enter the unit identification number, name, and hull number of the requisitioner, e.g., (3312) USS YORKTOWN (CVS-10).

Block D — Leave blank; used by the Inventory Control Points to indicate referral action.

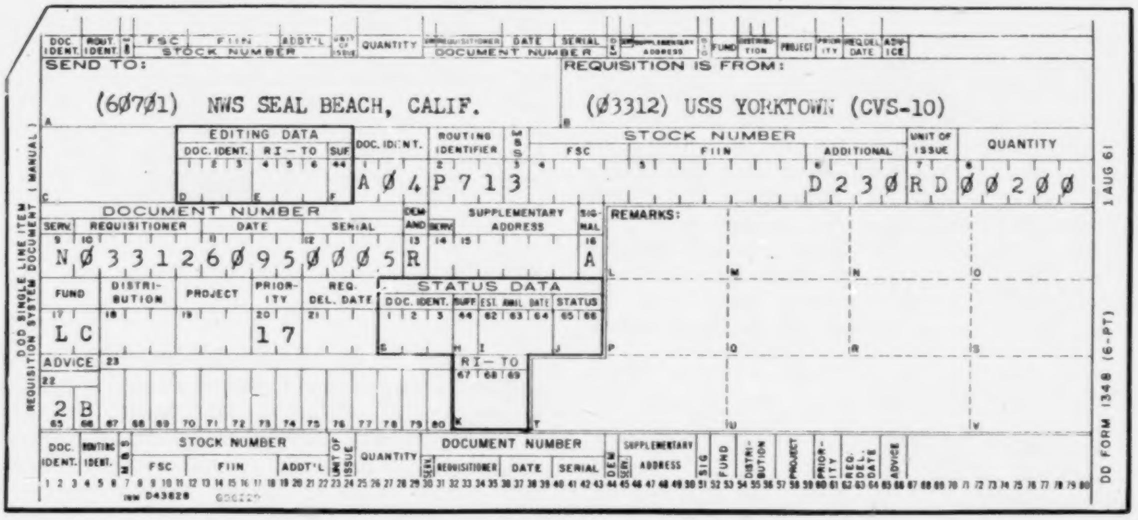
Block E — Leave blank; used by the Inventory Control Points to refer action to a specific supply point.

Block 1 — Document Identifier, a three digit code that identifies the basic type of administrative action, e.g., A4 identifies the document as a requisition for overseas shipment/ with DOD Ammunition Logistics Code Number. This Identifier (A4) normally will be used on ammunition requisitions from active naval vessels.

Block 2 — Routing Identifier, a three digit code which identifies a specific Inventory Control Point or Distribution Point, e.g., P71 identifies NWS Seal Beach. Enter the appropriate code to identify the activity to which the requisition is to be submitted. Routing Identifier Codes are listed in Appendix 7 of the NAVSUP Manual, Volume III.

Block 3 — Media and Status, a one digit code to indicate type of status to be furnished, e.g., digit 3 means exception status to the requisitioner by other means. Exception status consists of information relative to any action taken by the supply source other than issue of the material, e.g., requisition is rejected; requisition is referred to another activity for action; substitute item is furnished, etc. Normally, enter 3 in block 3.

Blocks 4, 5, & 6 — Stock Number, a fifteen digit space available for Federal Stock Numbers. It is permissible (and normally desired) when requisitioning ammunition to enter the DOD Ammunition Logistics Code instead of the Federal


DOD SINGLE LINE ITEM REQUISITION SYSTEM DOCUMENT (MANUAL)

SEND TO: (60701) NWS SEAL BEACH, CALIF.

REQUISITION IS FROM: (03312) USS YORKTOWN (CVS-10)

DOC. IDENT. A04 | ROUTING IDENTIFIER P71 | M&S 3 | STOCK NUMBER ADDITIONAL D230 | UNIT OF ISSUE RD | QUANTITY 00200

DOCUMENT NUMBER: SERV. N | REQUISITIONER 03312 | DATE 6095 | SERIAL 0005 | DEMAND R | SIGNAL A

FUND LC | PRIORITY 17

ADVICE 2B

REMARKS:

1 AUG 61

DD FORM 1348 (6-PT)

43.24

Figure 13-5. — Sample requisition (DD Form 1348).

Stock Number. Enter the DOD Logistics Code for the item requested in block 6, e.g., D230 identifies Projectile, 5in38, AAC.

Block 7—Unit of Issue, enter two letter unit of issue for item being requisitioned, e.g., EA, RD.

Block 8—Quantity enter quantity of the item required. If the quantity exceeds 99,999, additional requisitions must be submitted for the remainder.

Blocks 9, 10, 11, & 12—Document Number, a fourteen digit space for identifying the Requisitioner's branch of service and unit identification number, the Julian Date of the requisition, and the serial number of the requisition. In block 9, enter "N" for Navy. In block 10, enter the identification code number for your ship. Precede with zeros if this number has less than five digits. In block 11, enter the Julian Date on which the requisition is made out. In the Julian Date system, the first position represents the last digit of the calendar year.

The last three positions indicate the numeric consecutive day of the calendar year. For example: 6095 represents 5 April, 1966. The numeric consecutive day of the calendar year can be found on all government issue calendar pads. In block 12, enter the consecutive serial number of the requisition. If this were the fifth requisition submitted this year, its serial number would be 0005. Requisition serial numbers will not be duplicated on the same day.

Block 13—Demand Code, enter R to indicate a recurring demand. That is, a demand made to replenish material consumed, or expected to be consumed, on a recurring basis.

Blocks 14 & 15—Supplementary Address, a six digit space for entering the service code and unit identification number, if applicable, of activity other than the Requisitioner to receive or to be billed for material. When ordering ammunition directly from an ammunition facility, leave blocks 14 and 15 blank.

Block 16—Signal Code, enter single letter to identify the "ship to" and/or "bill to" address. For example, A stands for material to be shipped to, and billed to, the Requisitioner, B stands for ship to Requisitioner, but bill the supplementary address. Enter A in block 16 on ammo requests.

Block 17—Fund Code, enter appropriate two character Fund Code as prescribed in Appendix 14 of NAVSUP Manual, Vol. III. For example LC tells the supply activity (in this case, the ammunition depot) that the chargeable activity will be COMNAVAIRPAC and that the material ordered is consumable material.

Block 18—Distribution Code, activity in addition to the Requisitioner, or the Supplementary Address, to receive supply status. When applicable, and in accordance with Fleet Commander instructions, enter in the first position of block 18 the code letter identifying the activity to receive supply status. For example: L identifies Commander Service Squadron Three, U.S. Pacific Fleet. The last two positions designate the material cog. Ordinarily, block 18 will be left blank.

Block 19—Project Code, a spare for identifying requisitions of material for specific projects or programs. Ammunition request will rarely require a Project Code. If applicable, check Appendix 6 of the NAVSUP Manual, Vol. III for the appropriate Project Code; otherwise leave block 19 blank.

Block 20—Priority Code, enter the appropriate issue priority designator in accordance with the OPNAVINST 4614.1 series. Do not use other than routine priority code numbers without the weapons officer's full knowledge and approval.

Block 21—Required Delivery Date, the priority assigned in block 20 normally will determine the delivery time. Therefore, no required delivery date will be entered in block 21 except under the following conditions:

1. When the material is required before the priority delivery date to meet scheduled departure of a ship or deployment of a force assigned a Force Activity Designator III, or higher.

2. When the material is not required until after the priority delivery date because of overhaul schedule, etc.

Note: Use Julian Date if required delivery date is to be entered.

Block 22—Advice Code, enter the appropriate two letter code if any of the following instructions are considered essential to proper supply action:

2B—Do not substitute; deliver requested item only.

2C—Fill or kill; do not back-order.

2D—Furnish exact quantity requested.

2J—Do not substitute, do not back-order, fill or kill.

Blocks L through V — Remarks, used to convey any additional information not provided for in the regular format. Use of the Remarks section will be restricted to essential information. If used, Document Identifier A5 or AE must be entered in block 1.

Blocks D through K — Requisitioning activities will not use these blocks. These heavy black bordered blocks are used only by the Inventory Control Points to indicate referral actions. When an Inventory Control Point takes action which would require status information to be sent to the Requisitioner, these blocks are used to indicate the action taken.

REQUISITIONING AMMUNITION BY NAVAL MESSAGE

When time is of the essence, requisitions may be transmitted by naval message, telephone, or radio. Naval message requisitions will be prepared in the following format:

> A04/P71/3/D230/RD/ZERO ZERO TWO ZERO ZERO/N3312/6095/0005/R/BLNK/A/LC/BLNK/BLNK/17/BLNK/2B

Refer back to figure 13-5 as we breakdown the above message and identify each part. A4—document identifier/P71 — routing identifier/3—media and statue/D23 — ammunition logistics code/RD — unit of issue/2 — quantity/N3312 — requisitioner's unit identifier/695 — Julian Date/5 — serial number/R — demand code/BLNK — supplementary address/A — signal code/LE — fund code/BLNK — distribution code/ BLNK — project code / 5 — priority / BLNK — required delivery date/2B — advice code.

Requisitions transmitted verbally by telephone or radio shall be relayed in exactly this same coded format. Normally, written confirmation of these verbal requisitions is not desired.

The answers to any further questions you may have on MILSTRIP in regard to requisitioning ammunition can be found in Volume III of the NAVSUP Manual.

MAINTENANCE AND MATERIAL MANAGEMENT

The 3-M System, like any other system or program, is only as good as the personnel who make it work. Your role in the system as a PO1 or CPO will include the training of lower rated personnel in its use, as well as the scheduling and supervision of maintenance.

Our discussion will be in broad terms and will concern itself with general aspects of the system. As a leading petty officer, however, you should keep abreast of new developments and changes to the system. Details on the system and changes related to it are available in the Maintenance and Material Management (3-M) Manual, OPNAV 43P2 (revised). Other sources of information include OPNAV instruction 4700.16 (revised), NAVORDSYSCOM instructions and notices, and directives issued by type commanders. In addition, information presented in this chapter supplements that of Military Requirements for PO 1 & C, NAVPERS 10057-C.

PLANNED MAINTENANCE SYSTEM OPERATION

The Navy, as well as the other services, is required to maintain all weapon systems in the maximum possible degree of combat readiness. Previous systems for controlling and accomplishing required maintenance could not keep pace with the growing complexity of shipboard maintenance, increased tempo of fleet operations, and constant decline in available resources. The standard Navy Shipboard 3-M System was implemented in 1964 in an attempt to solve these problems and to provide a more adequate system of collecting information required to support fleet equipment improvement projects. The 3-M System was designed to function as an integrated system which would improve the management of maintenance. It provided for the collection and dissemination of maintenance related information for use in developing better management and engineering analysis programs. Significant benefits were gained from this early program, particularly in the area of preventive maintenance control and effectiveness. It was recognized, however, that the original design of the 3-M System did not satisfy all the requirements of the system data users and did not represent the optimum approach to attaining and maintaining maximum fleet readiness.

The current (revised) 3-M System is the result of several years of concentrated effort to redesign the system for greater responsiveness to the most important needs of all Navy commanders and managers who are concerned with "maintenance" and "maintenance management." Better understanding of the problems involved may be gained from examination of the following definitions and explanations of those two terms:

1. "Maintenance" as defined by the Department of Defense, and by all common sense rules, includes servicing, repair, modification, modernization, overhaul, conversion, rebuilding, testing, reclamation, inspection and condition determination, and the initial provisioning and reprovisioning of support items.

Thus it is apparent that "maintenance" covers just about every aspect of effort concerned with Navy hardware after initial procurement stages; and it may even be involved in those earlier stages as a result of design, reliability, or maintain-ability studies.

2. "Maintenance Management" by defininition not only includes supervision of actual maintenance action of effort, but it also includes all forms of effort to plan for and support the maintenance efforts. In brief, a maintenance manager is anyone who makes decisions that affect maintenance or the support of maintenance.

A system could not be designed to satisfy all the demands of so many users without imposing unacceptable demands on the system operators. For this reason the revised 3-M System is designed to establish a realistic balance of these demands. It will provide the maintenance related data most needed by all levels of maintenance managers, without imposing a burdensome work load on the maintainer. It will also provide a tool to assist fleet personnel in utilizing available manpower, material, and maintenance opportunities more effectively.

CONCEPT AND OBJECTIVES

The revised Shipboard 3-M System is an integrated management system which, when fully implemented and properly used, provides for orderly scheduling and accomplishment of maintenance and for reporting and disseminating significant maintenance related information. It is composed of two sub-systems, the Planned Maintenance Sub-System (PMS) and the Maintenance Data Collection Sub-System (MDCS); and it forms the nucleus of a shipboard maintenance program which can contribute significantly toward achieving improved fleet readiness with reduced expenditure of resources.

The 3-M System will assist Navy operational and technical commanders in attaining and maintaining optimum Fleet readiness through the efficient and effective use of available resources. Specific objectives of the system are to:

- Define and achieve uniform maintenance standards, criteria and procedures.
- Assist operating forces by promoting effective utilization of available manpower, material, and maintenance opportunities, and by reducing the total administrative burden on maintenance personnel.
- Document the requirements for and the accomplishment of maintenance, and the utilization of maintenance assets.
- Increase knowledge of current ship configuration and identify desirable changes to existing configuration or improvements in new ship configuration design, through information gained by documenting maintainability and reliability experiences.
- Improve maintainability and reliability of equipments and reliability experiences. Improve maintainability and reliability of equipments and systems through uniform maintenance disciplines and improved engineering practices, identification of essential design changes to existing equipments/systems, and documentation of experience data of value in new equipment/system design.
- Accurately identify the cost of maintenance in terms of manpower, material and funds, and reduce these costs through maintenance efficiencies and management effectiveness.

SHIPBOARD 3-M ORGANIZATION AND RESPONSIBILITIES

The 3-M System provides the commanding officer of a ship with a tool for planning and management of shipboard maintenance and for reporting maintenance related data. The ship's organization, however, must incorporate all applicable portions of the 3-M System to derive maximum benefit from its use. While there is no single master plan which will ensure optimum effectiveness in all classes and types of ships, there are certain organizational concepts and responsibilities which must be adopted by every ship in which the 3-M System has been installed. The following paragraphs define the basic structure for a shipboard 3-M organization (figure 13-6) and the responsibilities assigned within that organizational framework. Amplifying instructions, as deemed necessary, are promulgated by fleet and type commanders.

Commanding Officer

The commanding officer has overall responsibility for ensuring that ship maintenance is accomplished in accordance with the procedures of the 3-M System and that the system functions effectively within his command. He shall ensure that appropriate personnel have received adequate formal 3-M training and frequently meet with the executive officer, 3-M coordinator and other maintenance managers to review the status of material readiness, discuss 3-M matters, and provide necessary guidance and coordination. He shall satisfy himself, through periodic inspections, that the system is properly installed and is being properly used within the ship.

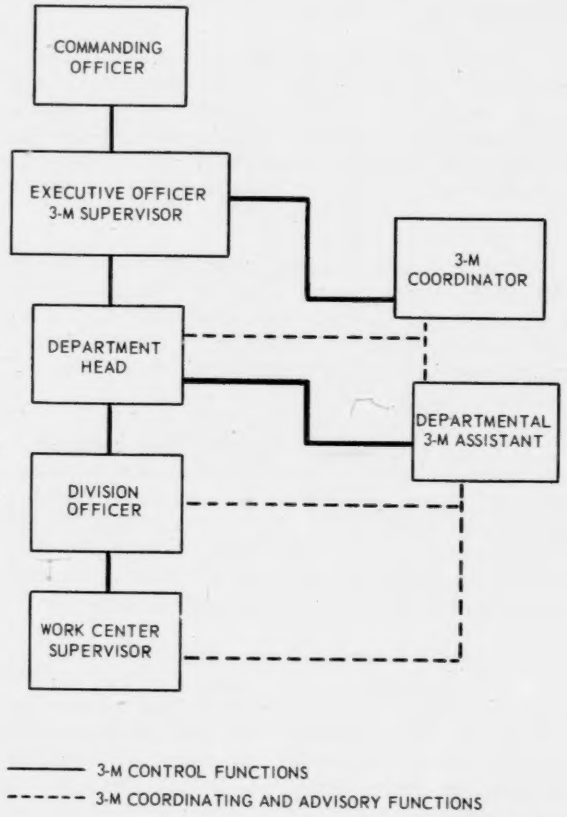
Executive Officer

The executive officer is responsible to the commanding officer for the overall organization and operation of the ship's 3-M program. He will provide the supervision and coordination required to ensure system effectiveness.

The executive officer normally is a graduate of the Command and Executive Shipboard 3-M Indoctrination Course. He, therefore, is thoroughly indoctrinated with regard to 3-M techniques/procedures. In addition, he must keep himself abreast of current 3-M System policies and directives.

In the performance of his duties, the executive officer regularly reviews and monitors the operation of the shipboard 3-M program to ensure compliance with current directives. He also acts as chairman for periodic 3-M meetings with department heads and the 3-M coordinator. The foregoing factors enable him to provide regular briefings to the commanding officer which report the status of preventive maintenance, MDCS documentation, and overall material readiness. Additional duties include the following:

- Supervising the drafting of ship's directives pertaining to the 3-M System.
- Coordinating the incorporation of 3-M training into the ship's training program, and ensuring that selected 3-M personnel receive adequate and effective training.
- Ensuring that an effective coordinated program is established for filing and controlling retained copies of deferral documents and feedback forms.
- Ensuring that an effective coordinated system is used for the use and accountability of JCNs (Job Control Numbers).



180.117

Figure 13-6.—Typical shipboard 3-M organization.

3-M Coordinator

The 3-M coordinator is responsible to the executive officer for coordination and direct supervision of all facets of the ship's 3-M program. Where personnel resources permit, this will be the primary duty of an officer (senior petty officer on very small ships) who has had extensive formal training in 3-M. In all other cases it must be clearly defined as the most significant of all collateral duties.

As a principal assistant to the executive officer, the 3-M coordinator must be cognizant of the details of planning and administering the ship's maintenance program under the 3-M System. In this capacity, he advises and assists department heads, division officers, departmental 3-M assistants and work center supervisors on matters concerning the 3-M System, keeping them informed of changes to the 3-M System as they occur. The duties of the 3-M coordinator require that he regularly monitor departmental use of the 3-M System so that he can keep the executive officer advised with regard to the effectiveness of its operation.

The 3-M coordinator supervises the operation of a functional Maintenance Data Collection Center. A requirement for its effective operation is the prompt submission of all 3-M System documents originated by the ship. The 3-M coordinator will establish procedures for screening documents for correctness, accuracy, and legibility and submitting them at least weekly to the Type Commander Data Processing Facility. Another requirement is the maintaining of corrected, up-to-date copies of 3-M System directives, publications, reports, accountability log for PMS changes, and an updated master feedback file.

In the area of training, the 3-M coordinator ensures that the shipboard training program realistically and accurately supports the ship's 3-M training requirements. He will provide technical assistance for 3-M training when requested. Additionally, the 3-M coordinator will:

- Ensure that the ship's installation has been properly accomplished and is maintained up-to-date.
- Establish an effective coordinated system for the control and use of JCNs.
- Ensure that sufficient supplies are on board to support the 3-M System (software and hardware).
- Ensure that 3-M System reports and summaries received by the ship are properly distributed and used.

Department Head and Departmental 3-M Assistant

Each department head is responsible for the effective operation of the 3-M System within his department. As an aid to managing his 3-M responsibilities, the department head may assign an officer or competent petty officer the duty of departmental assistant. Both should be formally trained in the 3-M System.

Unless otherwise directed by the cognizant fleet of type commander, the department head supervises all cycle and quarterly scheduling of departmental maintenance and ensures proper supervision of other departmental 3-M functions, including:

1. Regular inspections of 3-M operations within the department, including weekly review of the departmental maintenance control board.
2. Provisions for emphasizing to the personnel of his department the importance of properly scheduled maintenance and the proper documentation of the maintenance performed.
3. A determination that departmental personnel are properly trained and motivated concerning the 3-M System, and that departmental 3-M training records, files and publications are properly maintained.
4. The conducting of periodic meetings with division officers and work center supervisors to ensure a continuing knowledge and necessary corrdination.
5. Assistance to division officers and work center supervisors as necessary in obtaining 3-M supplies and scheduling weekly maintenance.
6. The signing of cycle and quarterly schedules prior to posting.

Division Officer

The division officer is responsible to the department head and should have formal training with regard to 3-M requirements. He assists the department head in scheduling maintenance required for the equipment under his cognizance. He ensures, by daily inspections, that weekly schedules are in accordance with the departmental quarterly schedule and that the required maintenance is being properly performed and reported. In order to keep the department head informed of the status of 3-M within his division, the division officer will conduct periodic meetings with all divisional work center supervisors.

Being responsible for divisional training, the division officer will incorporate 3-M training into the divisional training plan. This will include the maintaining of up to date training records. Finally, as an assistant to the 3-M coordinator, he will screen all MDCS documents generated within his division for completeness, accuracy, and promptness of submission.

Work Center Supervisor

The work center supervisor, normally the senior rated man in the work center, is responsible to the division officer for the effective operation of the 3-M System within his work center. He also requires some form of formal training with regard to 3-M techniques/procedures.

The work center supervisor personally schedules (on the weekly schedule) work center maintenance and supervises its accomplishment. Follow-up action requires that he ensure an up-to-date indication of work center maintenance on the departmental maintenance control board. If, for any reason, scheduled maintenance is not accomplished, the work center supervisor advises the division officer or department head via appropriate channels.

As an assistant to the division officer, the work center supervisor ensures maximum use of the 3-M System as a training aid within the work center. This training should be reflected in divisional training records. Additional responsibilities are maintaining adequate supplies of 3-M materials within the work center, promptly submitting correct MDCS documents and maintaining control and accountability of work center Job Sequence Numbers (JSNs).

Maintenance personnel are responsible to the work center supervisor. Their duties include, but are not limited to, (1) reading the weekly schedule every day and performing the PMS actions scheduled; (2) knowing how to fill in MDCS documents; and (3) informing the work center supervisor of completed and incompleted PMS actions and any problems encountered in performing them.

Supply Officer

The supply officer will coordinate the efforts of his department to best support the ship's maintenance effort and will include the establishment of procedures for control of internal issue of materials. Specific duties will be dependent upon the level, intermediate or organizational, of maintenance with which he is associated. (Destroyers, cruisers, aircraft carriers, mine craft, etc. provide maintenance situations which are at the organizational level. Tenders, repair ships, etc. are examples of maintenance organizations at the intermediate level.) Tenders and repair ships have a Supply Support Center (SSC) within their supply department. This requirement is optional at organizational maintenance activities.

Rotatable pools for repairable items are maintained aboard intermediate maintenance activities. Pre-Expended Bin (PEB) material is maintained at both the intermediate and the organizational levels. We discuss this in greater detail later in this chapter.

PLANNED MAINTENANCE SUB-SYSTEM

The increasing complexity and quantity of equipment required for the operations of a modern Navy have necessitated the continuous updating of maintenance procedures and the refinement of maintenance management organization at all levels. These improved procedures are necessary for the assurance of equipment readiness, the key to operational readiness.

The Planned Maintenance Sub-System (PMS), when installed, supersedes all previous maintenance systems or programs. Where there is a difference between stated requirements of the Planned Maintenance Sub-System and other technical publications or systems (NAVSHIPS TECH Manual, Ordnance Publications, etc.), the Planned Maintenance Sub-System requirements will prevail. When a difference occurs, a feedback report shall be submitted advising higher authority of the conflict.

Procedures which appear to adversely affect the reliability of equipments or the safety of personnel are reported to the appropriate authority via the feedback system mentioned in the last paragraph. This feedback system provides a direct line of communication through all levels, from the maintenance personnel aboard ship to the systems command responsible for the specific equipment.

The PMS has been developed to provide each ship, each department, and each supervisor with the tools to plan, schedule, and control shipboard planned maintenance effectively. The PMS is expressly designed to reduce complex maintenance to simplified procedures, easily identified and managed at all levels. Benefits to be realized from this system are:

- INCREASED RELIABILITY.—The PMS increases reliability by performance of regular planned maintenance to reduce the need for major corrective maintenance.

- INCREASED ECONOMY.—Proper planned maintenance will reduce casualties and save the cost of many major repairs and/or equipment replacements.

- BETTER PLANNING.—The PMS facilitates the efficient and convenient programming of work load by advancing planning. Inevitable changes in the ship employment schedules are readily accommodated.

- RECORDS.—Simplified records contain data useful for shipboard maintenance management.

- IMPROVED MANAGEMENT.—The convenience and flexibility of the PMS, as well as the reduction of breakdowns and irregular hours of work, help to prevent "morale breakdown" and enhance the feeling of effectiveness on the part of officers and men.

- TRAINING.—The PMS is an excellent aid for on the job training and completion of practical factors required for advancement in rate through the use of MRCs and weekly schedules. When properly utilized, the weekly schedule ensures a balanced workload and job rotation of personnel which maintains a high degree of qualified personnel for all maintenance tasks. The MRC is an excellent tool to be used for qualifying personnel in practical factors for advancement in rate.

- MAINTENANCE.—Provides improved continuity of maintenance control.

MAINTENANCE DATA COLLECTION SUB-SYSTEM

The Maintenance Data Collection Sub-System (MDCS) provides a means for maintenance personnel to record information pertaining to preventive or corrective maintenance actions. The system uses coded data elements for recording much of this information to standardize the data collected and to facilitate its processing and use. The failure and corrective action information recorded on the maintenance action documents, and the material usage information recorded on associated supply documents, is retrievable through this system for engineering analysis and maintenance history.

In addition, the system makes it possible to report the need to delay accomplishment of required maintenance to indicate the principal reason for this delay. This information is retrievable for analyzing maintenance and logistic support problems. It is also used for developing a Current Ships Maintenance Project (CSMP) file which will assist in improving the planning and coordination of the ship's workload. For those maintenance actions which have been deferred because of a requirement for technical skills or special equipment not available on board ship, the MDCS makes provisions for documenting a work request to repair activities. Follow-up reporting by these activities upon completion of requested work contributes to the detail and depth of maintenance information available through the MDCS.

Overview of System Operation

Routine maintenance action reporting actually is accomplished on a multi-purpose maintenance data collection form which, occasionally, is augmented by additional information reported on a related supplemental data reporting form. The Maintenance Data Collection Forms, OPNAV Forms 4790-2K/L, are used in reporting the completion or deferral of a maintenance action, or to request needed assistance. The data elements which must be completed to report any one of these categories of maintenance information have been grouped together in separate, clearly labeled sections of the form to simplify data recording and to facilitate Automatic Data Processing (ADP).

Tools of the PMS

Accomplishment of a ship's assigned missions, in a reliable and competent manner, is dependent upon the ship's personnel possessing the ability to execute a uniform pattern of shipboard maintenance. For this reason it is of utmost importance that all maintenance personnel be familiar with proper use of the "tools of the PMS" in implementing and accomplishing planned maintenance. The "tools of the PMS" are listed in table 13-1.

The items listed in table 13-1 are provided in the initial installation and replenished in the update packages for each activity. Additional or replacement forms for the Cycle Schedule, Quarterly Schedule, Weekly Schedule, 4790/7A PMS Feedback Forms and PMS Manuals may be obtained through the Navy supply system. Additional or replacement PMS hardware may be obtained from NMMFO in accordance with current type commander directives. The NMMFO in Norfolk and San Diego will provide replacement MIPs, MRCs and EGLs, in response to feedbacks received or through regular quarterly force revision distribution.

The items listed in Table 13-1 are described in Military Requirements for PO 3 and 2, NAVPERS 10056, and PO 1 and C, NAVPERS 10057.

Table 13-1.—Tools of the planned maintenance Sub-System

Colloquial Name		OPNAV No.
PMS Manual		43P1
Documentor's Handbook		43P5
MIP (Maintenance Index Page)		4700-3
MRC (Maintenance Requirement Card)		4700-1
ELG (Equipment Guide List)		
Cycle Schedule	Standard	4700-4
	Compact	4700-8
Quarterly Schedule	Standard	4700-5
	Compact	4700-9
Weekly Schedule	Standard	4700-6
	Compact	No OPNAV No. Assigned
PMS Feedback Form		4790-7A
Accountability Log		
Maintenance Control Board - Standard and Compact		
Manual/MRC Holder		
Weekly Schedule Holder - Standard and Compact		

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Another type of administrative duty performed by a leading GM is that of passing on technical information in that form of sketches and drawings.

Technical Sketching

The ability to make quick, accurate freehand sketches is a valuable means of conveying technical information or ideas. A sketch usually is made freehand but they may be made on graph paper, or with a ruler or pencil compass. A sketch may be of an object, an idea of something you are thinking about, or a combination of both.

There are no standards for technical sketching. The sketch can be drawn pictorially so that it actually looks like the object, or it can be sketch of the object showing different views.

Preparing rough technical sketches saves time and the use of a cross-section (graph) paper is especially useful when basic layout mathematics are needed for mechanical drawing.

As a PO1 or Chief you may be called upon to make freehand sketches of electrical, electronics, mechanical, and hydraulic systems. Sketches and drawing may be used as teaching aids, for job order work requests, or as part of a Beneficial Suggestion for a unit of ordnance equipment. The best information on the basic techniques for making all types of freehand sketches and drawings is contained in Blueprint Reading And Sketching, NAVPERS 10077.

ORDNANCE LOGISTICS INFORMATION SYSTEM (ORDLIS)

The Ordnance Logistics Information System (ORDLIS) is a program within NAVORDSYSCOM which combines, in one central automatic data processing facility, both Configuration Status Accounting (CSA) and Logistics Support Requirement (LSR) information. The availability of CSA status and relatable LSR information in one common data processing bank provides NAVORDSYSCOM with the ability to provide precisely tailored, highly visible, cost effective logistic support information to all appropriate echelons of NAVORDSYSCOM and to other activities requiring this information. For example, the ORDLIS program provides information for current fleet modernization programs and certain other information to NAVSHIPSYSCOM for use in their Ship Alteration Management Information System (SAMIS). The ORDLIS program is based on the premise that logistic support must be precisely tailored to the exact configuration status of a given ship using automated procedures to ensure both accuracy and economy. The program includes current and projected status and planning information.

The ORDLIS program provides ship configuration change information for planning purposes. A positive end product is the (Post-Overhaul-Projected) SAIL, Ship Armament Inventory List. In addition, ORDLIS CSA records (current or projected) precisely define LSR information required for Allowance Parts Lists (APLs), Publications Requirements Lists (PRLs), Maintenance Index Pages (MIPs), and Equipment Identification Codes (EICs). This is accomplished using fully automated procedures.

To obtain and maintain complete and accurate identification of the current configuration status and location of all non-expendable ordnance equipment, NAVORD provides (primarily through the Naval Ordnance Systems Support Offices, Atlantic and Pacific) on-board ship assistance in verifying configurations of ordnance systems, reviewing and updating SAILS, and assisting ships to obtain necessary ordnance systems publication, test equipment and repair parts support. However, NAVORDSYSCOM depends upon shipboard personnel, custodians of non-expendable ordnance equipment to report system/equipment installation, removal or ORDALT accomplishment in accordance with current instructions.

A continuing review of ORDLIS data required for the identification of LSRs requires that the basic elements of identity, location, ORDALT status, and equipment changes be reported in a timely and proper manner. As a senior petty officer, you should be aware that SAILs are used in conjunction with other ORDLIS records to identify, (to SYSCOMs, CNO and DOD) what non-expendable ordnance equipment is installed, and (to appropriate SYSCOM activities) what logistic support a ship should receive. You, therefore, should keep yourself abreast of current methods for reporting changes to the SAIL. Configuration information from SAIL changes and MDCS (3-M) reports are used by NAVORDSYSCOM to update SAIL and other ORDLIS records.

The importance of timely and proper reporting of changes to non-expendable ordnance equipment configurations (anotating of SAIL at prescribed times, submitting of SAIL change reports, and appropriate utilization of MDCS data) cannot be overemphasized. The ORDLIS program provides information and data for a multitude of purposes including the following:

- The Department of Defense Staff, supported by OPNAV personnel, uses ORDLIS fire control information to verify and evaluate the effectiveness of joint and combined national assignments to war plans and operation orders from a radio-frequency interference aspect.
- The Chief of Naval Operations uses ORDLIS information to rapidly identify installed weapon systems and, therefore, capabilities of ships operating throughout the world. ORDLIS information, in conjunction with Movement Reports and Operational Status and Casualty Reporting System information, provides a better picture of the operating forces and some of the detail needed for operational decision making.
- The Chief of Naval Material uses ORDLIS information, combined with NAVSHIPS SAMIS information, to evolve cost-effective alteration and conversion recommendations to the Chief of Naval Operations. This influences policy and planning with regard to the current Fleet Modernization Program (FMP). The FMP is used for workload planning as well as budgeting.
- NAVSHIPSYSCOM uses ORDLIS information, combined with Force Level Plans, to plan and manage the Shipyard Modernization Program. Additionally, ship type desks in NAVSHIPSYSCOM use ORDLIS information for coordination of 180-day (information) letters with ORDALT Accomplishment Requirement (OAR) letters.
- NavSupSysCom uses ORDLIS information for the Cordinated Ships Allowance List (COSAL)

generation and validation as well as for spare parts plans, budgets, and purchases. Maintenance Data Collection sub-system information is combined with ORDLIS information for Allowance Parts List (APL) purification.

- Shipyards and type commanders use ORDLIS information to maximize the effectiveness of regular overhaul workload planning.

HANDLING OF CLASSIFIED MATTER

It is the responsibility of every officer and man in the Navy to safeguard military information. Since you may often require the use of classified matter in your work, an understanding of the proper safeguards, dissemination, and control of such matter is essential.

The Department of the Navy Security Manual for Classified Matter, OpNav Inst. 5510.1C (or latest revision) is the controlling guide in safeguarding classified information. However, there is no adequate substitute for continuous day-to-day practice in the proper methods of handling classified material.

CLASSIFICATION OF DOCUMENTS

Matter which requires classification in the interests of national defense is assigned the lowest classification category appropriate thereto in accordance with the Department of the Navy Security Manual for Classified Matter. Classified matter, including extracts therefrom, is classified according to its own content and not according to its relationship to other classified matter.

GRADES OF CLASSIFICATION

Official information which requires protection in the interests of national defense shall be limited to three categories of classification which, in descending order of importance, shall carry one of the following designations: Top Secret, Secret, or Confidential. No other designation shall be used to classify defense information, as requiring protection in the interests of national defense, except as expressly provided by statute.

Top Secret

The use of the classification Top Secret is limited to defense information or material which requires the highest degree of protection. Top Secret is applied only to that information or material, the unauthorized disclosure of which could result in exceptionally grave damage to the nation, such as:

1. Leading to a break in diplomatic relations, an armed attack on the United States or its Allies, or a war.

2. The compromise of military plans or scientific or technological developments vital to the national defense.

Secret

The use of the classification Secret is limited to defense information or material the unauthorized disclosure of which could result in serious damage to the nation, such as:

1. Jeopardizing the international relations of the United States.

2. Endangering the effectiveness of a program or policy vital to the national defense.

3. Compromising important military or defense plans, scientific or technological developments important to national defense.

4. Revealing important intelligence operations.

Confidential

Information or material classified Confidential is placed in the category in which unauthorized disclosure could be prejudical to the defense interest of the Nation.

Certain types of Confidential information may still be identified by the term "Confidential Modified Handling Authorized."

The designation "Confidential - Modified Handling Authorized" has been eliminated and will no longer be applied to Confidential information or to information received from foreign governments or international organizations and classified as "Restricted." Documents or other material on hand which already have been marked shall have the designation "Modified Handling Authorized" lined out or otherwise cancelled as they are withdrawn from the files for any purpose other than destruction. The modified handling procedures prescribed for the protection of "Confidential - Modified Handling Authorized" are cancelled. All such material shall be protected as Confidential material.

Restricted Data

The term "Restricted Data" is not a category of classification, but is assigned because of the general subject of the documents. It applies to all data concerning the design, manufacture, or utilization of atomic weapons; the production of special nuclear material; or the use of special nuclear material in the production of energy—unless such data or materials have been declassified or removed from the category by the Atomic Energy Commission.

Information is marked Restricted Data (Top Secret), (Secret), or (Confidential) according to the protection it should receive. It is declassified when the Atomic Energy Commission decides it may be published without undue risk to the defense and security of the Nation.

The term "Formerly Restricted Data" applies to that classified defense information which has been removed from the Restricted Data category and cannot be released to foreign nationals except under specific international agreements.

RESPONSIBILITY

The Chief of Naval Operations is responsible to the Secretary of the Navy for all policies relating to the security of all classified information within the Naval Establishment. Under the Chief of Naval Operations, the Commander, Naval Intelligence Command, has been designated as the officer primarily responsible for the protection of classified information. Therefore, the Naval Intelligence command formulates and promulgates naval policies which relate to the security of classified information.

Loss or Compromise

Any person having knowledge of the loss or possible compromise of classified matter must report the fact immediately to his commanding officer. The commanding officer then takes the proper action as outlined in detail in the Security Manual, chapter 8.

Violations of regulations pertaining to the safeguarding of classified information, but not resulting in its loss, compromise, or disclosure, are acted upon by the commanding officer.

It is vital that every GM who handles classified material be completely familiar with paragraph 0815 of the Security Manual. This paragraph sets forth the policy for disciplinary action in the case of violations of security.

It must always be remembered that the GM is responsible for the classified material in his care. Anyone who willfully or negligently mishandles classified material is disciplined by his commanding officer or by a court-martial, depending on the circumstances. If mishandling results in loss or compromise, disciplinary action is almost certain to be severe.

Personal Censorship

There is no way of estimating how many battles have been lost, how many ships were sunk, or how many lives were sacrificed because someone casually, or in a moment of boasting, unintentionally betrayed a vital military secret.

It is quite natural for a man to be proud of the work he is doing. He wants to share this pride with his friends and family. This would be fine with most jobs in the Navy. However, for the Gunner's Mate, this very often may not be done. Enthusiasm towards one's work is clearly a desirable trait, but not when it results in discussing classified information. There is only one safe conversational policy to follow and that is to say nothing about the work one does to anyone.

To keep the silence, one should decline to discuss official matters by skillful maneuvering of the conversation or by outright refusal to talk shop.

Security

Security is a means—not an end. Rules which govern security of classified matter are much the same as gunnery safety rules. They do not guarantee protection, and they do not attempt to meet every situation.

Security regulations are not intended to restrict the initiative of mature individuals. With common sense and mature thinking, it is possible to obtain a satisfactory degree of security with a minimum of sacrifice in operating efficiency.

The Department of Defense employs a security formula which is simple in principle. It is based on the theory of circulation control—the control of the dissemination of classified information. Therefore, knowledge or possession of classified information is permitted only to those who actually require it in the performance of their duties, and then only if they have been determined to be trustworthy. This is sometimes called the principle of the "need to know."

Control

Each individual in the Department of the Navy should take every precaution to prevent deliberate or casual access to classified information by unauthorized persons. Some of the precautions will be discussed in this section.

When classified materials are removed from stowage for working purposes, they should be kept face down or covered when not in use.

Visitors not authorized access to the particular classified information within a working space should be received in a specially designated visting space.

Classified information should never be discussed over a telephone. Remember also that a telephone scrambler device does not ensure security.

If, for any reason, a room must be vacated during working hours, all classified material in the room should be stowed in its proper containers.

At the close of the working day a system of security checks should be carried out to ensure that the classified material is properly protected. All classified material must be properly stowed.

In the event of a fire alarm or other emergency, classified material is stowed in the same manner as at the end of a working day. Each person who has classified material in his possession at the time of a fire alarm or other emergency assures that the material is properly safeguard.

An accurate record of destruction of classified material is as important as its destruction. A certificate of destruction of nonregistered Top Secret and Secret documents is always prepared. The certificate is retained for a period of two years by the command destroying the material. The certificate provides complete identification of the material destroyed, the date of destruction, and it is signed by the officer authorizing destruction.

AUTOMATIC DECLASSIFICATION

Documents require certain additional markings in accordance with the Automatic, Time-Phased, Downgrading and Declassification System. This system divides documents into four groups according to the type of information contained, and provides for standard downgrading or declassification for certain documents, based on elapsed time since origination and the type of information included. The complete details of the system may be found in OpNav Instruction 5500.40B or subsequent issue.

REPRODUCTION OF CLASSIFIED INFORMATION

Classified information normally shall be prepared, printed, and reproduced by Navy or Department of Defense facilities. When this is not possible, preparation, printing and reproduction of classified information is authorized only by the following:

1. For Top Secret:

   a. As specifically approved by the Director, Navy Publications and Printing Service.

2. For Secret and Confidential:

   a. Government Printing Office.
   b. In commercial facilities having an active facility clearance at least as high as the classified information to be processed and obtained in accordance with the requirements of the Department of Defense Industrial Security Regulation and when specifically approved by the Director, Navy Publications and Printing Service.

Local Printing, Duplication and Reproduction of Classified Material

From a security viewpoint, the printing, duplicating, or reproduction of classified material poses many problems; it contributes to the increasing volume of classified material; it permits quick and easy production of uncontrolled material containing classified information; the equipment or processes require care or special procedures to prevent or eliminate latent impressions or offset versions of the classified information; and a quantity of excess and waste material is produced which can also contribute to compromise of the classified information. Therefore, local commands must require close supervision and careful control of all reproduction facilities under their jurisdiction. Of particular importance is the need for controlling and supervising the use of office copying machines for the printing, duplication, or reproduction of classified material and to assure the proper recording and safeguarding of the classified material reproduced by such means. In no event, however, shall classified material be reproduced without the approval of competent authority.

When authorized by competent authority, classifed material may be produced or reproduced and then only in as few copies as possible, and the number of copies should not exceed that required to meet a known need.

Classified material produced or reproduced by any means shall be recorded in accordance with Articles 0610, 0611 and 0612 of OPNAVINST 5510.1C.

Samples, waste, or overruns resulting from the reproduction process shall be safeguarded according to the classification of the information involved, and shall be destroyed promptly as classified waste.

When classified material is reproduced, the reproduced material shall be marked with the classification and other special markings which appear on the original material from which copied or reproduced.

When thermal copy paper is used to reproduce documents upon which classified information has been recorded, only Type 1 (back coated) thermal copy paper shall be used.

When slip sheets are placed between the diazo process film sheets in the reproduction process of classified information the slip sheets should be handled as classified waste.

DESTRUCTION OF CLASSIFIED DOCUMENTS

Documentary record material made or received in connection with the transaction of public business, and preserved as evidence of the organization, functions, policies, operations decisions, procedures, or other activities of any Department or Agency of the Government, or because of the informational value of the data contained therein, may be destroyed only in accordance with the Act of July 7, 1943, controlling the disposition of such material; c.192, 57 Stat. 380, as amended (44 U.S.C. 366-380). Destruction of (a) classified records so authorized by Record Disposal Schedules, (b) nonrecord classified documents as defined in SEC NAV Instruction 5212.5 or subsequent revisions, or (c) classified waste material shall be made by one of the following methods.

Top Secret, Secret and Confidential material may be destroyed by burning, pulping, pulverizing, or shredding, provided destruction of the classified material is complete and reconstruction is impossible.

a. Destruction of classified material shall be accomplished in the presence of two witnessing officials. A witnessing official shall be a commissioned officer, warrant officer, enlisted man E-7 or above, or U.S. civilian employee in grade GS-7 or above. If none of these categories is available, a mature and reliable enlisted man E-5 or E-6, or U.S. civilian employee in grade GS-5 or GS-6 may be designated as a witnessing official. All persons witnessing the destruction of classified material must have a security clearance at least as high as the category of material being destroyed, and they shall be thoroughly familiar with regulations and procedures for safeguarding classified information.

b. When appropriate, certificates of destruction shall be prepared and signed by the witnessing officials.

c. Witnessing officials shall observe the complete destruction of the classified documents.

d. Residue shall be checked to determine if destruction is complete and reconstruction is impossible.

e. When burning classified material, efforts must be made to ensure that portions of burning material are not carried away by wind or draft.

f. Witnessing officials shall take precautions to prevent classified materials from being carried away by wind.

Destruction of Equipment

When it is necessary to dispose of equipment that must remain classified, destruction shall be accomplished by any means that will prevent recognition and reconstruction or by jettisoning in random water area of at least 1000 fathoms depth. Provisions of this Article do not apply to classified crypto-equipment. Consult the effective publication for the disposition of such equipments under routine and emergency conditions.

Records of Destruction

1. An accurate record of destruction of classified material is as important as its destruction. Proper accounting procedures, together with accurate records of destruction, provide official information as to the status of classified material.

2. A Certificate of Destruction of nonregistered Top Secret and Secret documents shall be prepared. The certificates shall be retained for a period of 2 years by the command destroying the material. The certificate shall provide complete identification of the material destroyed, the date of destruction, and it shall be signed

by the officer authorizing destruction and the witnessing officials, one of whom may be the official authorizing destruction. In the case of Secret documents only, use of routing sheets, mail logs, or other similar administrative records in lieu of a Certificate of Destruction is authorized, provided that all necessary information (complete identification of the material destroyed, date of destruction and signatures of two officials one of whom is to be the official authorizing destruction) is included. A Certificate of Destruction shall be signed by witnessing officials when the material actually has been destroyed or when torn and placed into waste bags for central disposal.

3. Certificates of destruction shall be prepared for all classified equipment destroyed. The certificate shall be retained for a period of 2 years by the command destroying the equipment, and a copy of the certificate shall be forwarded to the technical bureau systems command, or office responsible for procurement of the equipment.

EMERGENCY DESTRUCTION

Commands located outside the 50 United States and all afloat commands shall include in their destruction plans provisions for an emergency involving the danger of capture of classified material. In an emergency involving the danger of capture of classified material, the importance of beginning its destruction sufficiently early cannot be over-emphasized. The consequences of such destruction would be relatively unimportant when measured against the possibility of compromise through capture. Destruction plans of each activity will require of personnel at levels, the highest degree of individual initiative practicable in preparing for and in actually commencing required destruction. Particular care will be taken to indoctrinate all personnel to ensure their understanding that, in such emergencies and when required, they will initiate necessary destruction under the plan without waiting for specific orders. Lists shall be prepared which show the locations of classified material, personnel responsible for destruction, and the recommended place and method of destruction.

Priority for Emergency Destruction

1. Classified Communication Material. Insofar as humanly possible, cryptomaterial shall not be permitted to fall into enemy hands. In general, emergency destruction of classified communications material shall be carried out as follows:

a. First priority — Cryptographic material. (Detailed information concerning the order of destruction of cryptographic material is contained in the effective editions of KAG-1 and RPS-4).

b. Second Priority — Noncryptographic communication material by order of classification, beginning with the highest classification.

2. Other Classified Material. Emergency destruction of other classified materials shall be carried out in order of priority as follows:

a. Classified material pertaining to current and future plans and operations.

b. Classified material pertaining to standing operating or tactical procedures.

c. Equipment of a classified nature together with pertinent, technical, descriptive and operating instructions.

d. Remaining classified material. The order of destruction will follow classification, the highest classified material being destroyed first.

Accessibility for Emergency Destruction

1. Classified material shall be readily accessible at all times for emergency destruction by assigned personnel. When provisions in shipboard emergency destruction plans include jettisoning publications as a means for emergency destruction, document sinking bags are to be available for this purpose.

2. Material to be destroyed first shall, when practicable, be marked in a distinctive manner and stowed in the most accessible location.

3. Keys and safe combinations to spaces where classified material is stored may be kept in designated locations, safeguarded by proper security arrangements.

PERIODIC INSPECTIONS— TYPES AND REQUIREMENTS

As it should be safe to assume that you are fully familiar with the various types of internal shipboard inspections (those conducted by the C.O. or other officers of your own ship), we will cover only external type inspections here. By external, we mean any inspection conducted by an activity or command outside of your own ship. There are three types of external inspections: (1) operational, readiness, (2) material, and (3) administrative.

OPERATIONAL READINESS INSPECTION (ORI)

The operational readiness inspection (ORI) usually is conducted in the final stages of refresher training (REFTRA). The ORI evaluates the ship's offensive and defensive capabilities. A comprehensive battle problem is part of the ORI. ORI inspections usually are conducted by teams from a fleet training group, but may be conducted by representatives of the type commander at any time. Inspectors from either source will not be content with a broad determination of the ship's effectiveness in battle. In fact, a good part of the inspection consists of interrogating individual members of the crew. Questions are asked and simulated battle conditions are placed in effect to enable the inspectors to grade the individual's flexibility, versatility, and general training level.

MATERIAL INSPECTIONS

A material inspection can be conducted by the type commander at any time. All equipment in your charge is checked for proper operation, and to determine whether preventive maintenance measures are in effect. An INSURV (Board of Inspection and Survey) material inspection is also conducted at least once every three years. INSURV inspections usually are held before a shipyard availability period, and are apt to be even more exacting than the type commander's inspection. Material discrepancies should be noted in your CSMP on Deferred Action Form 4790/2k. An inspection file will be kept in the weapon's office but it would be a good idea for you to keep your own file on inspection discrepancies. Besides being an aid in correcting faulty maintenance practices, it should be very helpful in preparing for the next inspection. You should not list minor discrepancies that can be immediately corrected by ship's force in the CSMP, but they may of course be included in the inspection file.

ADMINISTRATIVE INSPECTION

An administrative inspection is a check of all administrative procedures, the availability of administrative materials, plus a spot check of equipment condition. The degree of the latter is at the discretion of the inspecting officer, and is related to an inspection of preventive maintenance procedures. The type commander's "admin" is the most involved, but the fleet training group also conducts an admin as a part of their arrival inspection. Don't forget, the most important aid in preparing for an admin inspection is the type commander's administrative checkoff list.

CHAPTER 14

MAINTENANCE

Up to now in your career as a Gunner's Mate, the part you have played in the maintenance field of ordnance equipments has been one of the "worker." That is, your main concern has been doing the routine maintenance required for your equipment upkeep.

Now, as a Senior Gunner's Mate, your job is to administer the various maintenance programs needed to keep ordnance systems ready. To have a good maintenance program, you must know where to go for information on repair parts, on current maintenance programs, on the types of test equipments necessary for maintenance, and on all safety precautions applicable to electrical, electronic, mechanical, hydraulic, and pneumatic equipments.

Immediate correction of minor irregularities may avoid major malfunctions. Since proper operation of a weapon system requires the precise synchronization of many parts, only qualified personnel should adjust or replace equipment.

Maintenance can be defined as that operation or groups of operations by which an item or assembly is sustained in functional condition or restored to a functional condition. The necessity for maintenance is determined during the course of normal operations under different environmental conditions. The degree of maintenance which may be required is determined by the availability of technically qualified personnel, by necessity, by time, and by the extent of authorization.

As a leading Gunner's Mate, a decision between repair and replacement of a part may be based on your knowledge of the construction and functions of the part and of the repair limitations to a part. Structural damage to ordnance equipment due to metal fatigue may call for replacement periodically.

To ensure proper operation after repair or replacement, many different types of adjustments to the equipment must be made. These adjustments include critical tolerances of electrical, electronic, mechanical, hydraulic, and pneumatic parts.

The methods, techniques, and safety practices used in performing all types of maintenance shall be such as to permit the job to meet final inspection and test before normal operation.

MAINTENANCE SKILLS

In performing any type of maintenance, a GMG must use knowledge and skills of two types. First, he must have specific information relating to the particular equipment he is to maintain and repair. Second, he must possess and use certain general skills and knowledge which apply to many kinds of equipment.

The specific information required consists of detailed step-by-step procedures approved for a specific piece of equipment. This information always is found in system OPs.

You have acquired the general maintenance skills and information by progressing to your present rate. The procedures generally follow the practical factors which you must complete as part of your qualifications for advancement. Procedures in soldering, use of basic handtools, performance of basic electrical measurements with devices such as voltmeters, ammeters, and ohmmeters are examples of some of the general skills in maintenance.

Now that you are preparing for GMG 1 or C, you must be prepared to teach the basic skills to lower rated men and, at the same time, increase your knowledge and skill so you can take care of advanced work on a weapon system. You must learn more about the overall and continuing plan of maintenance and the responsibilities of administration as well as technical duties in maintenance.

SCHEDULED MAINTENANCE

Scheduled maintenance prevents and detects failures, and maintains a high degree of operational readiness. Scheduled maintenance consists of inspection and test procedures, cleaning procedures, and lubrication procedures. These procedures are presented in the maintenance sections of equipment OPs and on separate Maintenance Requirement Cards (MRCs). The MRCs are cards that detail the procedures and equipment to use when performing maintenance tasks.

RESPONSIBILITIES OF GMG IN THE MAINTENANCE PLAN

A study of the quals on maintenance shows that the GMG 1 must be able to "overhaul, repair, and adjust,..., test and adjust,..., perform authorized maintenance,..., record system performance," while the GMG C must be able to "Plan, implement, and supervise, the maintenance and repair program."

Note that nearly all the "Knowledge Factors" are on the GMG 3 and 2 level, with the exception of principles of receiver-regulators, functions of fire control systems and equipment, and administrative and supply procedures.

The GMG 1 is expected to have knowledge of basic layout geometry for drawings and sketches, to be able to prepare freehand sketches, and to read and interpret diagrams and service instructions. The GMG 3 & 2 manual explained in some detail the use of different types of ordnance drawings in your work. Drawings of electrical, electronic, mechanical, and hydraulic systems are included. No additional requirements are stated for the GMG C; he needs to be able to teach the use of drawings and sketches and their interpretation.

The success of any planned maintenance program depends to a very large extent on cooperation at the working level. Help your men to understand how their day-by-day work of lubrication, cleaning, and similar routine upkeep helps to prevent costly and time-consuming breakdowns and the consequent hard repair work.

The work of the PO 1 and C in administering the 3-M system of maintenance and the Maintenance Data Collection Subsystem (MDCS) are described in Military Requirements for PO1 & C, NAVPERS 10057. Planning the daily work of maintenance by his men (and himself) to carry out the ship's plan is the responsibility of the GMG 1 and C.

STEPS IN MAINTENANCE PROCEDURE

Preventive maintenance involves four major types of activity:

1. Periodic cleaning
2. Periodic lubrication
3. Periodic inspection
4. Periodic performance checks

Corrective maintenance is generally performed in three phases: (1) troubleshooting, (2) removal and replacement of parts, and (3) alignment and adjustment. There may be overlapping between corrective and preventive maintenance; there is no sharp dividing line.

Visual Inspection

All components, including explosives, receive frequent visual inspection. Although it is of limited value in detecting some types of weapons system troubles, it is the first method used in trying to find the source of trouble or potential trouble. Do not let it become a casual inspection. Normal ship vibration will cause screws and lugs to work loose; a good visual inspection will locate loosened ones. Loose terminal lugs and screws are a common source of trouble. Loose mounting bolts can be the cause of misalignment.

Cables should be inspected for looseness or damage at places where they enter equipment or at any other point in the cable run. Cables showing signs of damage or abuse should be either rerouted or protected. Particular attention should be given to the coaxial cable, which is easily damaged by dents or sharp bends.

Look for signs of overheating and faulty insulation. When these signs appear, the equipment may be blackened around the area of overheating. Check the condition of tubes and tube sockets. Sometimes the shock of gunfire loosens tubes in the sockets. The light bulbs on control panels may be loosened by vibration.

Inspect junction boxes and other unit covers to see that they are properly dogged down. Tighten all retaining bolts and dogs evenly and firmly, alternating between diametrically opposite bolts or dogs.

Visual inspection discovers leaks in hydraulic systems, dents and similar damage in pipes, tanks, and other components. The efficient operation of any hydraulic system depends to a great extent on the effectiveness of the seals in keeping the fluid in it. Fluid leakage can be discovered by visual inspection, though the accumulation of leaked fluid may be some distance from the leak and you have to trace it to its source. Do not "sell short" this simplest of troubleshooting methods; it can save much time and testing in locating troubles with your equipment.

Cleaning of Parts

One of the most important rules of preventive maintenance is "Keep it clean," and you have been reminded of this many times in your Navy career. Many of the equipments are highly machined and have close tolerances. Dirt, dust, or other foreign substances can cause the equipment to operate erratically. Grit can cause excessive wear of parts of a mechanism and can make it inaccurate. Moisture can cause corrosion, and this can cause inaccuracies in operation. Excessive grease or the wrong kind can hamper operation.

Scheduling of routine cleaning is part of your responsibility. In the 3-M as in previous systems of maintenance, the intervals of cleaning are based on normal conditions. If you have a situation other than normal, such as an extreme amount of dust, more frequent cleaning may be necessary. Prepare your daily and weekly schedules in accordance with the 3-M system and modify it to take care of any special situations on your ship. As each job is completed, check it off.

As supervisor and instructor of the men doing the cleaning of equipment, be sure that all safety precautions are observed. With any kind of solvent cleaner, ventilation is necessary to carry away fumes. Heat, fire, and sparks must be kept away from solvent cleaners. The Navy has tested many types of cleaners to find the best in effectiveness AND safety. Use the ones recommended in the OP for the equipment. Use the cleaners as sparingly as possible. Aside from cost savings, there are several reasons for this. Fumes will be less, reducing the health hazard; danger of fire is lessened; the solvent will not run into parts where it can do damage, as in electrical parts; and skin exposure is lessened, reducing the hazard of dermatitis. Because cleaners are used so frequently, the tendency to become careless with them needs to be held in check. The occurrence of a fatality from solvent fumes has heightened the stress on the need for ventilation when using solvents. Close the container of solvent when it is not in use, even though you must open it again in a few minutes. It is very easy for a container to be knocked over (as in the case of the fatality mentioned); besides, evaporation is continuous while the cover is off. A small amount of solvent on a clean, lintless cloth is the best way for cleaning small or delicate parts. Federal Specification PS-661, also called Stoddard solvent, or trichloroethylene, is the solvent most commonly used on mechanical parts to remove oil and grease (and dust, etc. embedded in it). Alcohol is used for cleaning cork and rubber parts. Always check the OP for the right type of cleaner to be used. OD 3000 describes the different types of solvents and cleaning compounds.

Arrange the layout of work so you have adequate working space, good lighting, and good ventilation. Planning the layout and the work sequence will do much to expedite the work, make it easier, reduce mistakes, and reduce hazards.

Lubrication

You know the importance of lubrication in the maintenance of all equipment. You are acquainted with lubrication charts and have used them in your maintenance work. As a GMG 1 and C you will prepare checkoff schedules from lubrication charts, OPs, on-mount instructions, or other sources, and supervise the work of lubrication. The types of lubricants and types of lubricating tools were discussed in GMG 3 & 2 rate training manual, and in OD 3000.

The parts of the launching system especially subject to corrosion are those that are entirely above deck and constantly exposed to sea spray and water. Maintain the paint on all painted surfaces and a protective coating of lubrication on unpainted surfaces. Flush, clean, and relubricate any bearing surfaces that have been flooded with salt water. Be sure to use the correct lubricant for the part being lubricated and for the weather conditions. Some cold weather lubricants must be used very sparingly to avoid "freezing" of parts. The lubrication charts, which have a NAVORD (NAVWEPS) drawing number, show all points requiring lubrication, give access locations, designate the required lubricants, and tell you how often to lubricate at each point.

Caution against overlubrication is especially important where electrical components are concerned. Oil and grease must be kept off insulation of cables, and other electrical parts. They cause switches and solenoids to malfunction, and will ruin motor armatures.

An excess of lubricant in gear housings can be a source of trouble. When the oil heats up during operation of the unit, it expands, and it may seep out and into parts where it will cause damage. Always check the oil level during maintenance, and do not add oil above the indicated oil level.

Other cautions in regard to lubrication are concerned with cleanliness. If there is dirt, lint, or gummy substance at the area to be lubricated, clean the area before adding fresh lubricant. When grease-lubricated bearings or bearing surfaces are disassembled, all the old grease must be removed and the bearings and housing washed with solvent before fresh grease is applied. The lubricating tool (grease gun, grease pump, oiler, etc.) also must be clean. Wipe it clean before using it and also wipe the point of application on the unit being lubricated. Before opening an enclosed unit, especially one that is gasketted to keep out dust and moisture, wipe the outside of the container. Do the work in a clean area, and place clean parts on a clean cloth or paper. Just a few grains of grit in a delicate instrument can be ruinous.

Maybe you already are observing all these cautions; see that the cautions are observed by the men who are helping you and are learning from you.

Several grease guns should be available for use by your group, so each one can be used for a different type of grease. If you have only one grease gun, you have to clean it thoroughly every time you have to use a different type of grease. Do not mix different types of lubricants.

In order to reach some parts for lubrication, such as the training circle, the train drive pinion, and elevation drive pinion, the equipment must be moved from its stowed position. Take great care to avoid injury to personnel. The air motor is used to move the equipment, NEVER use automatic movement to train or elevate the equipment during servicing.

Hydraulic systems need checking of the fluid level at different points in the system. On some components, as on the 5''/54 the fluid level may be noted through a viewing window. If the level is too high, loosen the plug at the bottom of the reservoir and drain enough fluid to bring it down to the required level. A dipstick inserted through the fill port is used to check the hydraulic fluid level in sumps. ALL hydraulic fluid MUST be strained into the hydraulic system through a 10-micron filter, even though it is being poured from a freshly opened can. Call upon your experience to impress on your men that the need for such care is not mere fussiness. You know the trouble just a little dirt in the hydraulic system can cause.

Tests

It is hardly an exaggeration to say that at any given moment, some part of a weapons system is undergoing test. The processes of maintenance, testing, repairing, and operational checkout are continuous. The formal planned maintenance program, the 3-M system, was established to prevent forgetting some components in the maintenance and test programs. Other ratings perform some of the tests—on the fire control system and the weapons direction equipment. The ship's maintenance plan for the weapons system included all of them. When you plan the assignments of your work week, you must coordinate the jobs with those in other units of the weapons system, and avoid interference in the performance of the work. Cooperation in planning and performance are essential for successful testing of a system. An understanding of the relationship among the parts of the system and the place of each in the whole is needed for intelligent cooperation.

The types of tests and frequency of tests are subject to change. The analysis of results with the 3-M system will reveal need for greater frequency of some tests and less testing in other cases. Always check the latest MRC.

SYSTEM PREVENTIVE MAINTENANCE

In some ordnance systems preventive maintenance components are built into a system which helps to discover incipient faults. Two of these components are a cycle time selector and a ground detection indicator.

Cycle Time Selector

The cycle time selector provides a means to check actual cycle time against a time cycle chart listed in the equipment's OP. A system that functions within its designated time specifications indicates that all adjustments are correct and that all equipments are functioning correctly. An equipment that deviates grossly from the cycle time specifications indicates a maladjustment or potential problem. For example, a hydraulic unit that overspeeds might have a plugged orifice or a malfunctioning metering valve. Large time deviations should be investigated and corrected. When to take corrective action in cases of cycle time deviations is a judgment made at the time of the test. Ignore minor discrepancies that do not interfere with the overall efficiency of the equipment. Judgment is refined as your experience as a GMG increases.

Ground Detection Indicator

The ground detection indicator is a continuous monitoring system designed to detect a system ground. Since most control circuits in ordnance systems are powered by ungrounded 115-v 60 Hz 1-phase current, the first ground is not very important from an operational point of view. However, if the first ground is not discovered, and a second develops, the result could be an illogical and destructive sequence of system operation. The reason for this is that two grounds act as an electrical conductor between the grounded components. When the ground detector indicates, by a light or buzzer, that some part of the control circuitry is grounded, the GMG must determine the location and cause of the ground. The elimination of most grounds and potential grounds is good maintenance and good housekeeping.

ELECTRIC SYSTEM MAINTENANCE

Electrical system maintenance in ordnance systems consists of taking insulation resistance readings of control circuits, electric motors, electric heaters, and firing mechanisms using a megger meter, checking adjustments on interlock switches and solenoid mounted switches used in gun loading and gun laying systems, and lubricating bearings of electric motors.

Most interlock switches require either monthly or quarterly checks to be sure that they are actuating and deactuating properly. In addition, some switches are electrically checked periodically to determine whether they are making and breaking as required, and some switch circuits are checked periodically for continuity.

INTERLOCK SWITCHES

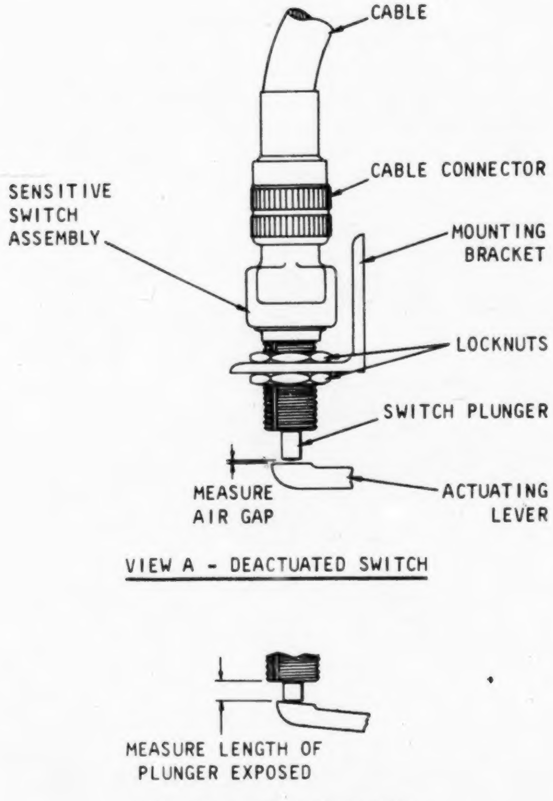
There are two basic types of interlock switches used in gun mounts: equipment-mounted interlock switches and solenoid-mounted interlock switch elements. The equipment-mounted switches are part of various gun loading and gun laying components, and indicate the status of those components. Solenoid-mounted interlock switch elements are an integral part of their respective solenoid assemblies. They indicate the status of solenoid position.

The types of equipment-mounted interlock switches used in a gun system are the microswitch and the proximity switch.

Microswitches (sensitive switches) figure 14-1, are of the standard type and are sealed plug-in units. The switches may be mounted on a stationary or a moving component. The moving part of the switch can be a straight plunger, or the plunger may have a roller attachment. Plungers are used where actuator motion is linear (fig. 14-1) and roller attachments are used where a camming surface acts on the switch, figure 14-2.

To adjust an equipment-mounted sensitive switch, loosen the locknuts with a wrench (the switch is secured to its bracket with either a locknut in a threaded hole or with two locknuts in an unthreaded hole). Then position the switch assembly in the bracket in an actuated or deactuated position, figure 14-1, in accordance with instructions listed in equipment OPs. In the case of a roller-attachment switch, adjust in half-turn increments. Final adjustment must be sure that the roller rides correctly on the actuating surface, figure 14-2.

When checking switches, ensure that the required adjustments and the required position of the associated components are in accordance with current OP instructions. Adjustment for some switches is made when they are actuated, whereas the adjustment for other switches is made when they are deactuated. Failure to follow adjustment procedures could cause major damage and injury to personnel.

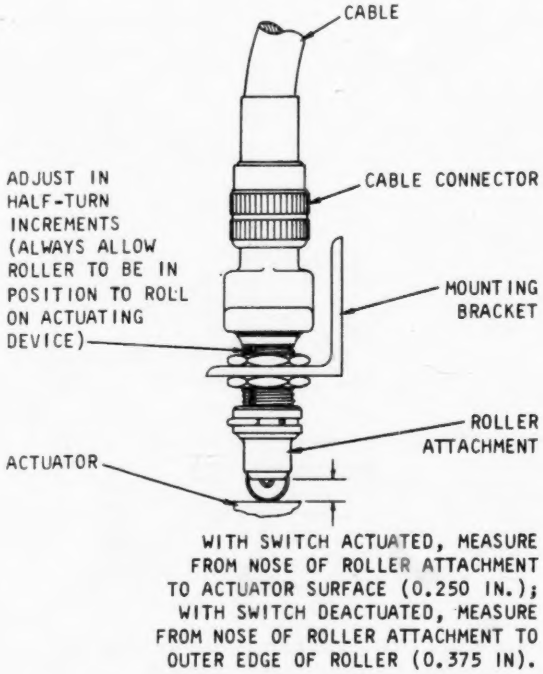

CABLE
CABLE CONNECTOR
SENSITIVE SWITCH ASSEMBLY
MOUNTING BRACKET
LOCKNUTS
SWITCH PLUNGER
MEASURE AIR GAP
ACTUATING LEVER
VIEW A - DEACTUATED SWITCH
MEASURE LENGTH OF PLUNGER EXPOSED
VIEW B - ACTUATED SWITCH

83.90(53C)A
Figure 14-1.—Adjustment measurement for plunger-actuated sensitive switch.

Proximity switches, figure 14-3, are hermetically sealed, magnetically operated switches. To actuate the switch, a magnet is placed near it and the switch contacts snap closed. Removing the magnet opens the switch contacts. The switch elements sensitive to a magnetic field are in the threaded end. A magnetic actuator, generally moved by a lever, piston, or cam, deactivates or activates the switch. When checking proximity switches, use nonferrous feeler gages (aluminum or brass).

Solenoid-mounted Interlock Switch Elements

Solenoid-mounted interlock switch elements indicate the status of solenoid armature position.


CABLE
ADJUST IN HALF-TURN INCREMENTS (ALWAYS ALLOW ROLLER TO BE IN POSITION TO ROLL ON ACTUATING DEVICE)
CABLE CONNECTOR
MOUNTING BRACKET
ROLLER ATTACHMENT
ACTUATOR
WITH SWITCH ACTUATED, MEASURE FROM NOSE OF ROLLER ATTACHMENT TO ACTUATOR SURFACE (0.250 IN.); WITH SWITCH DEACTUATED, MEASURE FROM NOSE OF ROLLER ATTACHMENT TO OUTER EDGE OF ROLLER (0.375 IN).

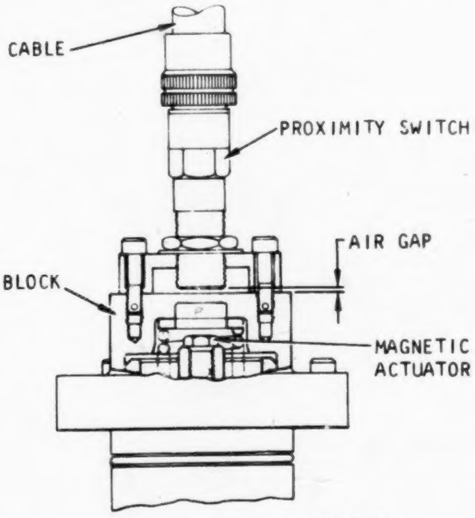
83.90(53C)B
Figure 14-2.—Adjustment measurement for roller-actuated sensitive switch.

Each switch is actuated by an actuating leaf which is pressed against the switch button by an adjusting screw (figure 14-4). A common adjustment procedure applies to all solenoid-mounted interlock switches. Observe the following precautions when adjusting switches.

1. Ensure that hydraulic power is not available to valve blocks when adjusting switches in associated solenoids. Remove and retain appropriate accumulator safety switches while working.
2. Ensure that train and elevation systems are not running unless needed to establish correct conditions for adjustment.
3. Do not jumper 115 vac to solenoids or bypass interlocks to energize solenoids.

To check or adjust solenoid-mounted interlock switch elements, proceed as follows:

1. Remove solenoid cover or control housing cover.



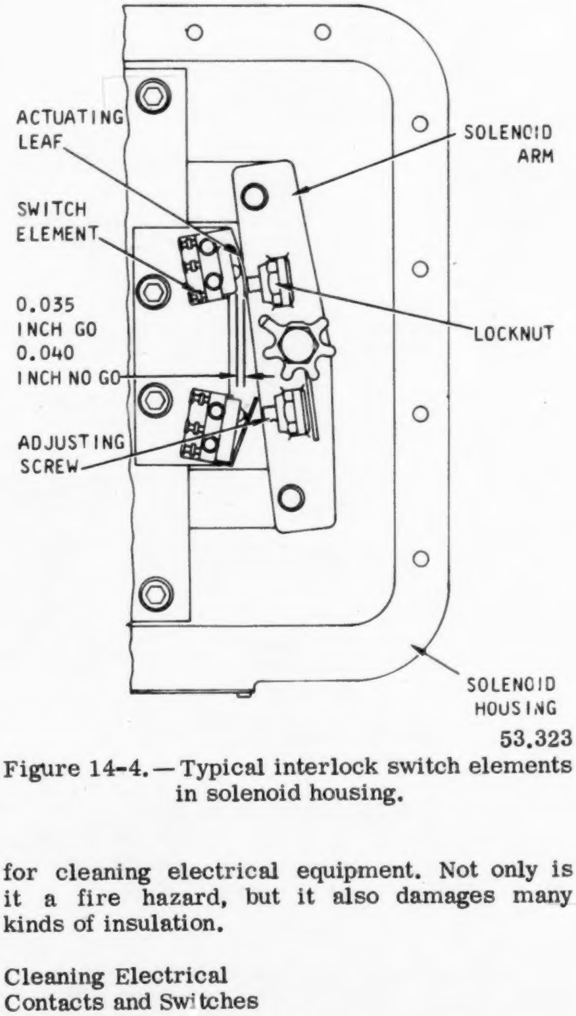
53.322
Figure 14-3.—Proximity switch.

2. Check distance between actuating leaf and switch element body. A 0.035-inch feeler should slide into clearance, but a 0.040-inch feeler should not fit (figure 14-4).
3. If clearance is too great or too small, loosen locknut and turn adjusting screw in or out to obtain desired clearance between actuating leaf and switch element.
4. Tighten locknut and verify switch setting before replacing cover.

When such items as switches, relays, solenoids, and synchros malfunction, do not attempt to repair them. Simply replace the faulty unit with a functional spare and adjust the new units for proper system operation.

Cleaning Electrical Components

Ever since you were handed a paint brush aboard ship, you have been warned not to paint electrical equipment. If you were heedless, you had to painstakingly clean it off, and you surely have learned your lesson. However, dust and dirt on electrical equipment still require removal regularly. When cleaning electrical and electronic equipment, always use an approved cleaning agent, such as Dry Cleaning Solvent, Federal Specification P-S-661. Alcohol should never be used for cleaning electrical equipment. Not only is it a fire hazard, but it also damages many kinds of insulation.



53.323
Figure 14-4.—Typical interlock switch elements in solenoid housing.

Cleaning Electrical Contacts and Switches

SWITCH MAINTENANCE.—While the switch itself is relatively simple to check, it sometimes offers difficulty in maintenance because it is inaccessible. After a visual inspection of the connections and the switch, a continuity test will indicate any malfunctions. When the switch mechanism is found to be defective, it normally is not repairable and therefore should be replaced.

When enclosed switches are used, failure to seal properly around cable openings causes the most difficulty. Atmospheric changes permit "breathing" of moist air into enclosures with improperly sealed cable openings, and the moisture in the air may condense within the switch enclosure. The condensation can short across the switch terminals and can corrode the switch actuators in a manner that may make them inoperative. This difficulty can be corrected by careful sealing of openings or by using hermetically-sealed switches. Hermetically-sealed switches will also prevent dust and dirt from reaching the contacts and thereby causing high resistance and open circuits.

Some switches are damaged during installation, particularly those with plastic housings. Proper care in installing or replacing plastic enclosed switches will eliminate this.

Some switches depend upon pressure for their operation. These switches have adjustments so that they will operate at the correct time or pressure. In many cases if the adjustments are not accurate, damage can result.

RELAY MAINTENANCE.—The relay is one of the most dependable electromechanical devices in use, but like any other mechanical or electrical device, relays occasionally wear out or become inoperative for one reason or another. Should relay inspection show that a relay has exceeded its safe life, the relay should be removed immediately and replaced with another of the same type. Care should be exercised in obtaining the same type replacement because relays are rated in both voltage and amperage.

As guides for spotting potential relay trouble during preventive maintenance, the following are suggested. Check for charred or burned insulation on the relay. Check for darkened or charred terminal leads coming from the relay. Both of these indicate overheating. If there is even a slight indication that the relay has overheated, it should be replaced with a new relay of the same type. An occasional cause of relay trouble is not the fault of the relay at all, but is due to overheating caused by the power terminal connectors not being tight enough. This should always be checked on preventive maintenance.

It is not recommended that covers be removed from semisealed relays in the field. Removal of a cover in the field, although it might give useful information to a trained eye, may result in entry of dust or other foreign material which may cause contact discontinuity. What is even more serious, removal of the cover may result in loss of or damage to the cover gasket. One of the prime advantages to hermetically-sealed relays is that they cannot be taken apart.

Relays can be ruined by the use of sandpaper or emery cloth for cleaning the contacts. A BURNISHING TOOL should be used for this purpose. Two types of burnishing tools are stocked at naval supply activities, and either type can be obtained through regular supply channels. The appearance and use of one kind of burnishing tool are shown in figure 14-5A. The surfaces of the tool that are used to clean the relay contacts should not be touched by the fingers prior to use; and after use, the burnisher should be cleaned with alcohol.

When relays contain bent contacts, no attempt should be made to straighten them with longnose pliers. Such an attempt often causes further damage with the result that the entire relay must be replaced. Bent contacts can be straightened effectively by using a CONTACT BENDER. The bender can be made locally from 0.125-diameter rod stock according to the dimensions shown in figure 14-5B.

Be sure the power is off and remains off while you are working on an electrical contact or switch, or relay.

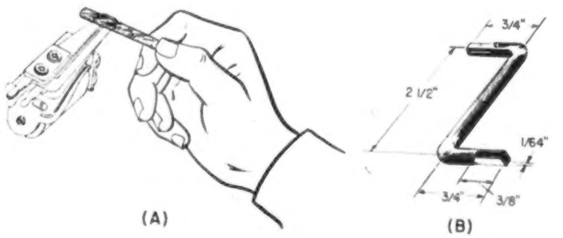
ELECTRONIC MAINTENANCE

Technical maintenance is normally limited to replacing unserviceable subassemblies or parts and aligning, testing, and adjusting equipment. To perform effective maintenance, the GMG must have a good working knowledge of the basic principles of electronics. The only way to acquire this knowledge is by diligent study. The GMG must also be thoroughly familiar with the theory of operation of the equipments that he must service. A knowledge of the theory of operation can be acquired through a study of the equipment OPs.

Electronic Control Units

Electronic control units, such as a servo control unit used with the 5"/54 gun system, contain plug in type module boards and require only voltage tests and balance adjustments for their maintenance. The MR cards for these systems explain the maintenance tests required for proper amplifier balance and power supply voltages. The operation of an electronic servo control unit is explained in chapter 6 of this manual.

Ordnance control systems that use electric and electronic components not contained in a signal unit (an amplidyne power drive) and made up of transformers, relays, capacitors, potentiometers, electron tubes, and solid state circuits



12.242

Figure 14-5.—Relay special tools: A. Burnishing tool; B. Point bender.

need a planned maintenance program to keep them at a high degree of readiness. The type of maintenance for such equipments varies with the type equipment but generally is to ensure that there is no evidence of overheating of amplifier components, that there are no loose or broken parts (and tubes), or broken insulation, and that there is no corrosion, fungus, dirt, or moisture on the amplifier, amplifier chassis, or their related components.

When inspecting electronic and electrical components and there is evidence of fungus found on or near components, thoroughly dry affected areas, brush away the fungus, and treat with anti-fungicide spray MIL-G-7711A. When conducting maintenance on enclosed electronic equipment where desiccant bags are used, always install a new desiccant bag before replacing equipment access covers. When conducting maintenance operations on electronic or electrical components, ensure that approved insulating deck covering is installed in all areas where maintenance is being performed. In most cases major components, such as amplifiers, should be replaced by on board spare units and the defective amplifier sent to a repair facility.

On ordnance systems that use electric drive motors and motor generators, maintenance consists of inspection of brush assemblies for evidence of chips, cracks, or other damage, and an inspection of interconnecting wiring for loose or broken parts or insulation. If brushes are worn to one-half or less of their original length (1/2 inch long), replace brushes. For motor generators, rotate armature by hand to ensure that it rotates smoothly and freely. Inspect commutator for flat spots, scoring, and evidence of arcing.

ELECTRICAL AND ELECTRONIC FAILURES

Practically all electric shocks are due to human failure rather than to equipment failure. Equipment may suddenly fail and cause fatal shock even if skillfully designed for safety, thoroughly tested before use, and used in accordance with applicable safety precautions. This can happen, but rarely does. Nearly all of the shipboard deaths were caused by human failure manifested in one or more of the following ways:

1. Unauthorized use of, or unauthorized modifications to, equipment.

2. Failure to observe the applicable safety precautions when using equipment or when working on or near energized equipment.

3. Failure to repair equipment which was known to be defective and had previously given a mild shock to the users.

4. Failure to test and inspect equipment for defects, or failure to remedy all defects found by tests and inspections.

All of these failures may be summarized as a failure to observe applicable safety precautions.

Electronic and Electrical Safety

Use safety devices provided for ordnance systems as designed. Keep the safety devices operative and in good order at all times. Inspect all safety devices frequently. If safety devices are rendered temporarily inoperative on approval of competent authority, use signs or other appropriate means to warn personnel. Do not secure inoperative safety devices. Do not alter safety devices except by direction of NAVORDSYSCOM. Keep the covers of switches, circuit breakers, and other electrical equipments securely closed while powder and other explosives are exposed in the vicinity.

Do not close circuit breakers that have opened until the cause of the overload has been corrected.

Unless specifically stated otherwise, perform all checking and maintenance procedures with the equipment shut down (all power off). Always have available one person familiar with first aid procedures for electrical shock.

MECHANICAL MAINTENANCE

Mechanical maintenance is the routine inspections and tests of a weapons system mechanical adjustments. When a routine maintenance check reveals that a particular unit or assembly is out of adjustment, or when repairs are made as a result of wear or casualty to equipments, readjustment procedures must be performed. When mechanical adjustments or readjustments are performed, all electrical switch adjustments must be rechecked and adjusted as necessary. When both mechanical adjustments and switch adjustments are needed, always make the mechanical adjustments first.

The purpose of mechanical maintenance is to ensure that all elements of an ordnance system are in proper alignment with respect to a centerline reference point. On some ordnance systems, special tools and accessories are provided for mechanical testing and adjustments.

Torque Testing

On the 5"/54 gun system a hoist chain tensioning tool is used to test and adjust the lower hoist chain for proper tension. Figure 14-6 illustrates how the tension tool is connected to the hoist lower sprocket assembly for testing. Before inspecting and testing the lower hoist chain tension adjustment mechanisms, be sure that the lower hoist and loader motors are off and that the hydraulic pressure in both the lower hoist and the loader accumulator system have been dumped to tank.

Connect the chain tensioning tool to the lower sprocket adjustment arm as shown in figure 14-6. By means of the tool, apply 50 pound-feet of torque to the arm in the direction that will increase the chain tension. As the torque is applied, move the bumper seat over against the adjustment arm and take up chain slack by turning bumper guide against bumper discs until they are held snugly together between guide and seat. Lock adjustment by turning locknut against bumper guide.

Mechanical Adjustments

There are many mechanical adjustments which must be checked periodically in accordance with current 3-M system instructions. One such adjustment, for the 5"/54 system is to ensure that ammunition rounds are properly aligned with the fuze setting mechanism.

A round of ammunition is placed in the gun loading system transfer tray, figure 14-7. The projectile is positioned so that the projectile fuze is 5.500 ± 0.062 inches away from the retracted fuze pot. Component parts of the transfer tray assembly are adjusted so that the projectile fuze will be a fixed distance away from the retracted fuze pot. This adjustment ensures that, when the fuze pot is extended onto the projectile fuze, the projectile is in the correct position and distance from the fuze pot to receive the correct mechanical time fuze setting.

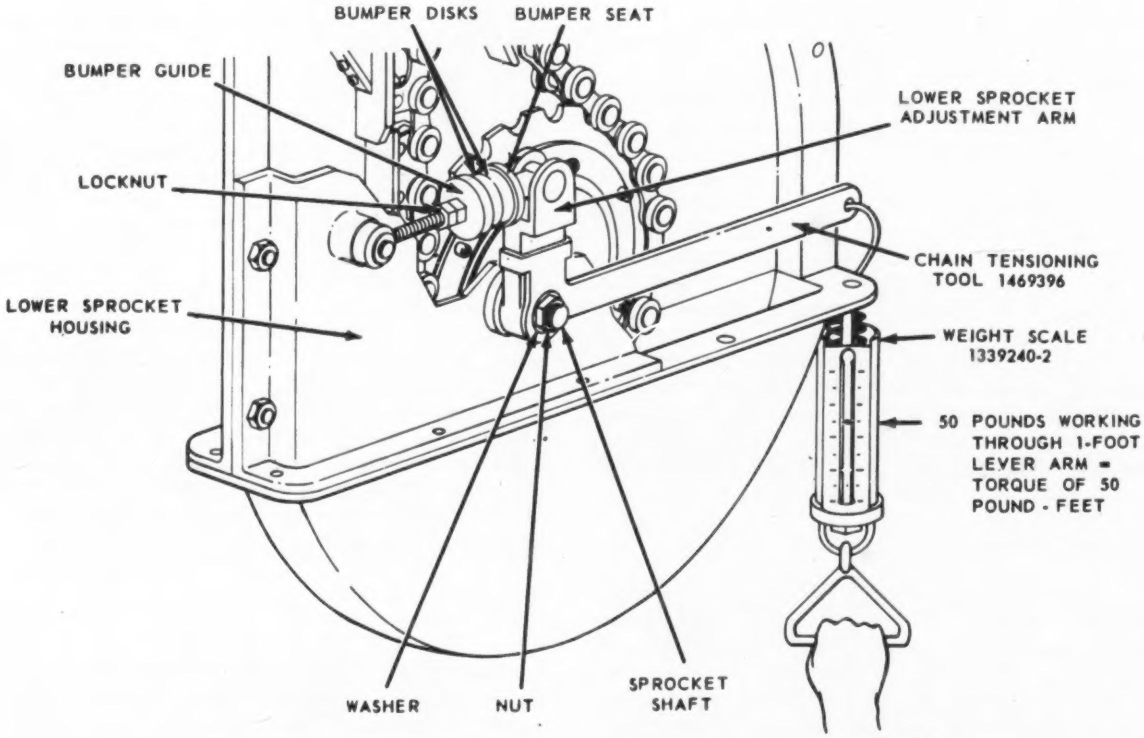
Anti-icing Systems

On some ordnance units an anti-icing system is used to prevent ice from accumulating on certain exterior surfaces of equipments during cold weather operations. An electric heating system warms up exposed areas to keep them clear of ice which could interfere with proper operation. Heating systems also help lubricants to perform satisfactorily within their various temperature ranges.

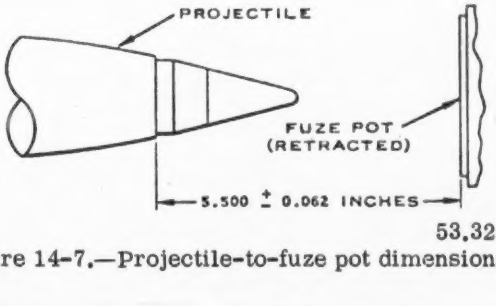
Inspection During Maintenance

When checking or making mechanical adjustments, inspect the lubricants used on sliding surfaces, linkages, plungers, and shafts. Inspect the moving parts and the lubricants to determine whether changes of lubricants are required. The following conditions should be observed:

1. Evidence of leaks, grease runout, scratched or marred parts or any imperfections or dry film coating such as cracking, blistering, flaking, etc.
2. Lubricant losses in exposed areas.
3. Contamination by grit, metal particles, dust, water and corrosion products.
4. Changes in appearance of lubricants other than mere color change.
5. Indications of excessive torque or drag in handwheels, door hinges, etc.
6. All moving parts for surplus lubricant, to prevent fouling by combination of dust, dirt, or sand with oil or grease.
7. Scoring of bearing surfaces or indications of metallic particles in the lubricant.
8. Evidence of willful tampering as indicated by presence of abrasives such as sand, emery, and pumice. Such materials can be detected by diluting the lubricant with cleaning solvent or gasoline and filtering.


BUMPER DISKS
BUMPER SEAT
BUMPER GUIDE
LOCKNUT
LOWER SPROCKET ADJUSTMENT ARM
CHAIN TENSIONING TOOL 1469396
LOWER SPROCKET HOUSING
WEIGHT SCALE 1339240-2
50 POUNDS WORKING THROUGH 1-FOOT LEVER ARM = TORQUE OF 50 POUND - FEET
WASHER
NUT
SPROCKET SHAFT

53.324
Figure 14-6.—Lower hoist chain tension adjustment mechanism.


PROJECTILE
FUZE POT (RETRACTED)
5.500 ± 0.062 INCHES

53.325
Figure 14-7.—Projectile-to-fuze pot dimensions.

When any of the previously observed conditions indicate the need for replacement or renewal of lubricants, the necessary corrective action should be taken immediately. If the specified materials or alternates are not available, substitutes may be used temporarily.

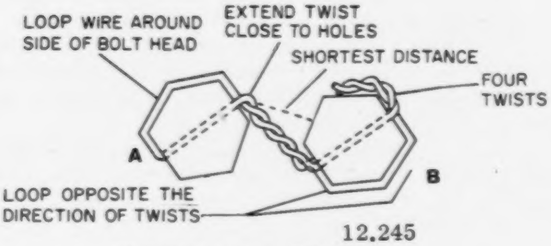
SAFETY WIRING

Screws, bolts, electrical and mechanical connectors, and other devices are safety wired as an additional security against the effects of vibration. Figure 14-8 shows the basic principles of safety wiring. The wire is threaded through the bolthead in such a direction that if a bolt tends to loosen, the wire will become tighter.

The wire used in safety wiring is usually made of annealed brass or annealed stainless steel. The size is not critical, depending mainly on the size of bolt being secured. The bolt used has a hole drilled through the head.

Refer to figure 14-8. The general procedure for safety wiring is as follows:

1. Thread the wire through the first bolt so that the wire exits on the side nearest the second bolt (point A).


LOOP WIRE AROUND SIDE OF BOLT HEAD
EXTEND TWIST CLOSE TO HOLES
SHORTEST DISTANCE
FOUR TWISTS
A
B
LOOP OPPOSITE THE DIRECTION OF TWISTS

12.245
Figure 14-8.—Safety wire.

2. Loop the wire around the side of the bolthead. The loop should be opposite the direction followed by the twisted wire so as not to interfere with it. Never kink the wire as it will be weakened at this point.

3. Twist the wire by hand; hold the wires so that an angle of about 90 degrees is formed between them. Do not use pliers as this tends to develop kinks and nicks, and to make the twist too small and tight.

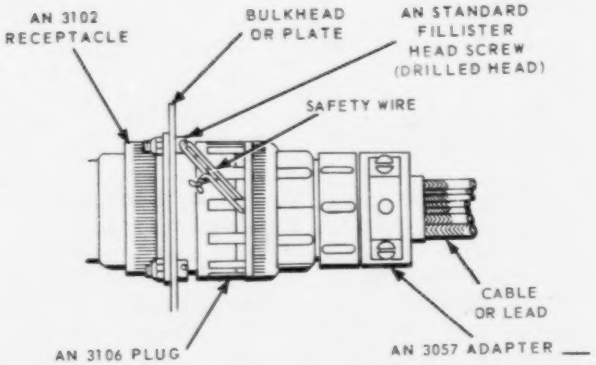
4. Thread one end through the second bolthead, and the other end around the side of the bolthead that is opposite to the direction of the twisted wire.

5. Pull both ends tight, and give a minimum of four twists on the far side of the second bolt.

6. Cut off the wire and bend it along the side of the bolthead.

Under conditions of severe vibration, the coupling nut of the AN connector may vibrate loose; and with sufficient vibration, the connector will come apart. When this occurs, the circuit carried by the cable will open. The proper protective measure to prevent this occurrence is a safety wiring attachment as shown in figure 14-9. Remember, any time a safety wire is NOT replaced, a failure may result.

The safety wire should be as short as practicable and must be installed in such a manner that the pull on the wire is in the direction which tightens the nut on the plug.



12.246
Figure 14-9.—Safety wiring for plug connectors.

Testing Handling Equipment

Ammunition handling equipments are tested at the time of their installation aboard ship. Subsequent testing should be made to detect any deterioration that has occurred during their use. For this reason, periodic testing and inspection of weapon and explosive ordnance handling equipment is needed to indicate the equipments ability to carry their rated load.

Explosive ordnance handling equipment used aboard ship shall be tested during regular ships overhaul, and after equipment modification or major repair but not less frequently than once every three years. Testing of shipboard handling gear is accomplished in accordance with NAVSHIPSYSCOM instructions.

Explosive ordnance handling equipment includes powered lifting devices using electric or pneumatic motors and manual devices using chain or wire rope which are geared with a mechanical advantage to a drive motor or manual device.

Tests shall be conducted in the following order:

1. Dynamic tests
2. Static tests
3. Full load test

Dynamic Overload Tests

Dynamic tests use a dynamic weight load which the equipment lifts to determine its dynamic overload characteristics. The handling equipment is dynamically tested to 125 percent of its rated load while underway or tested to 150 percent at dockside. The testing is done as follows:

a. Raise the load through the full lift height and lower again. The hoist is stopped three times in each direction to ensure proper operation of the brake.

b. Remove the load and visually inspect hoist and chain or cable for damage or permanent distortion.

Static Overload Test

Static tests use a static load applied to the equipment to test its structural strength. The equipment is tested to 150 percent while underway and to 200 percent of its rated load at dockside. After a dynamic test is completed, an additional test weight is added in accordance with the percentage required for static test. The hoist is raised and held in a fixed position for 20 minutes. If the hoist brakes hold without slippage for this period, the test is complete.

FULL LOAD TEST.—A full load test is given in accordance with the equipments nameplate rated load. Testing is done as follows:

a. Raise and lower equipment for the full height of the longest operational lift. Repeat for ten cycles. Moving the load up and down through full lift range is one cycle.

b. Powered and non-powered monorail equipment shall traverse entire length of rail twice with the load in the operating position. The dead man brake or track clamps shall be applied in three different locations during run.

Inspection After Testing

All tests shall be followed by a careful inspection. Any material found defective shall be replaced and the equipment shall not be used until material replacement is effected. When handling equipment demonstrates its ability to withstand required tests and pass inspection, it shall be tagged with the equipment identification, date of test, and the amount of weights used for the tests. This information should also be recorded in an ordnance log.

MECHANICAL SAFETY

Whenever any motion of power driven equipment is capable of inflicting injury on personnel or material not continuously visible to the persons controlling such motion, the officer or petty officer who authorizes the unit to be moved by power shall, except at general quarters, ensure that a safety watch is maintained in areas where such injury is possible both outside and inside the unit, and shall have telephone or other effective voice communications established and maintained between the station controlling the unit and the safety watch. These precautions are applicable especially when tests are being conducted on ordnance equipments.

Each MR card lists the applicable safety precautions to be observed before making any mechanical adjustments. In most cases these instructions include:

1. Ensuring electrical power is de-energized and properly tagged.
2. Ensuring accumulator pressures are dumped to tank.
3. Ensuring that safety links and securing pins are connected to prevent accidental movement of equipment.

HYDRAULIC SYSTEM MAINTENANCE

Satisfactory operation of hydraulic power drive systems is sustained by proper maintenance. Maintenance of hydraulic systems to prevent hydraulic fluids from becoming contaminated is very important. Reports received from fleet units indicate that contaminated hydraulic fluids have caused extensive damage to shipboard hydraulic systems. Cylinder barrels, valves, valve plates, pistons, bushings, and bearings are some of the units that have been damaged by contaminated hydraulic fluids.

Preventing Contamination

When hydraulic equipment is overhauled or repaired, several precautions should be followed to prevent contamination of hydraulic fluids.

1. Parts should be inspected for excessive wear and replaced when necessary.
2. All openings into hydraulic systems should be kept closed to keep out foreign materials.
3. When the hydraulic units are not being worked on, they should be covered with a clean cover.
4. Clean or replace the filter elements.
5. Do not weld, braze, or solder tubing after assembly of the equipment unless absolutely necessary because proper cleaning is more difficult.
6. Before reassembling, remove all dirt, sludge, water, or rust.

Flushing Hydraulic Systems

Sludge contains abrasives and causes excessive wear when circulating through hydraulic systems. Grit, as an abrasive, causes scoring on precision finished surfaces.

Dirt results in leakage, excessive wear, mutilation, and scoring of mechanical parts. If sludge, grit, or dirt collects in the system, it must be removed by flushing out the system with approved hydraulic fluids. A hydraulic system can be checked for contamination without disassembly by flushing out the system in the following manner:

1. Drain oil as completely as possible, and replace with clean hydraulic oil of the type used in the system.
2. Operate units at steady speed under light load for several minutes. Drain, renew oil, and repeat operation.
3. Allow unit to stand for one hour, if time permits.
4. Drain system thoroughly and fill again with clean hydraulic oil.
5. Check the system filters for any signs of contamination.

The system should not be operated during, or after draining, the fluid.

Whenever a hydraulic system is drained or opened for part replacement or maintenance, air may become trapped within the system. To prevent damage to associated components, thoroughly bleed the system before resuming hydraulic operation.

Diesel fuel oil shall not be used for flushing hydraulic systems in active service, owing to its poor lubricating properties and its contaminating effect on the subsequent fill of hydraulic fluid.

While being flushed with an approved hydraulic fluid, hydraulic systems can be operated at full load to raise the temperature of the fluid. Immediately following the warming operation, the system should be drained by opening all drain outlets and disconnecting the hydraulic lines to remove as much of the flushing medium as possible. All filter elements, screens and chambers should be cleaned with new fluid prior to refilling the system.

Hydraulic fluid which has been contaminated by continuous use in hydraulic equipment or has been expended as a flushing medium must not be used again; but, should be discarded in accordance with prevailing regulations.

Filtering

Before filling a hydraulic system or replacing fluid after flushing, the fluid to be placed in the system shall first be strained through a No. 200 (74 micron) sieve or preferably a finer sieve, No. 400 (37 micron) to remove the coarser particles which may be present. In addition, it is recommended that the fluid be pumped through a portable filter especially for hydraulic equipment containing servo or other systems having valves or other controls with close tolerance parts. Care should be taken to use the proper filter element to prevent the removal of additives.

Where micronic type filters are specified for the equipment, a 10 micron filter element may be used provided it does not remove additives.

Contamination Checks

Whenever it is suspected that a hydraulic system has become excessively contaminated, or the system has been operated at temperatures in excess of the specified maximum, a check of the system should be made. The filters in most hydraulic systems are designed to remove most foreign particles that are visible to the naked eye. However, hydraulic liquid which appears clean to the naked eye may be contaminated to the point that it is unfit for use.

Thus, visual inspection of the hydraulic liquid does not determine the total amount of contamination in the system. Large particles of impurities in the hydraulic system are indications that one or more components in the system are being subjected to excessive wear. Isolating the defective component requires a systematic process of elimination. Liquid returned to the reservoir may contain impurities from any part of the system. To determine which component is defective, liquid samples should be taken from the reservoir and various other locations in the system.

FLUID SAMPLING.—Liquid samples should be taken in accordance with the instructions provided in applicable technical publications for the particular system.

Some hydraulic systems are provided with permanently installed bleed valves for taking liquid samples; while on other systems, lines must be disconnected to provide a place to take a sample. In either case, while the liquid is being taken, a small amount of pressure should be applied to the system. This ensures that the liquid will flow out of the sampling point and thus prevent dirt and other foreign matter from entering the hydraulic system.

Before taking fluid samples, remove all foreign matter from around drain plugs and/or hydraulic lines. Use a clean 1 qt. bottle and drain at least 3/4 of a quart of fluid for each unit to be tested. Label each bottle with the name of the unit from which the fluid was removed. After removing fluid samples, replenish the fluid in each unit to maintain the correct fluid level. Deliver all samples to the maintenance group supervisor for testing.

In hydraulic systems which use accumulators, serious injury may result if the high accumulator pressures are not dumped to tank prior to taking samples. In such systems, ensure that all accumulator pressures are released by securing all accumulator motors and by pulling the handles of the system's manual unloading valves thus releasing the accumulator pressures.

Operation Under Environment Changes

Naval ordnance systems are usually designed to operate over a certain ambient temperature range; therefore, the material used in hydraulic systems must be selected to ensure reliable and efficient operation over this range. For example, shipboard ordnance normally is expected to operate satisfactorily over the temperature range -20° to 190°F.

Sluggish operation or failure of equipment to operate may be expected under cold weather conditions if preparations for entering such areas have not been adequate. Hydraulic systems should be prepared for cold weather operation by using appropriate low temperature hydraulic fluids. These fluids should be used in those cases where their unique properties would be advantageous. Hydraulic fluid MIL-F17111 is specified as power transmission fluid and is used in most hydraulic units with ordnance equipment. Normally, the highest operating temperature of MIL-F17111 should not exceed 190°F. In cold weather, exercising of the system for 15 minutes prior to service operation will generally result in improved operation. OD 3000, Lubrication of Ordnance Equipment, lists the properties of power transmission hydraulic fluids used for different temperature ranges. If hydraulic fluid must be changes for operation under extreme climatic conditions, low temperature fluids, such as MIL-H-5606 (-65 to 275°F.) may be used.

Storage of Fluids and Lubricants

The effects of over-heating, insufficient ventilation, and proximity to dangerous materials must be considered when storing hydraulic fluids and lubricants. Good housekeeping in storage areas must be stressed at all times.

There are no standard tests to determine the storage life of fluids and lubricants. The best available information is derived from practical experience and long-time observation. It is not good practice to allow fluids to be stored indefinitely since the accuracy and usefulness of storage life estimates is of doubtful value and is less reliable than periodic examinations of the fluids. Materials stored for service use should be examined semiannually. It is also a good practice to keep an accurate record of lubricants and fluids used, and use old stock first.

Inspection of Storage Areas

Before containers are stored, inspect them for corrosion, leakage, and complete closure of all plugs, caps, and covers. Remove all corrosion and repaint the affected containers.

During storage, inspect containers frequently for leakage and corrosion. If inspection indicates leaking containers, the materials should be transferred immediately to serviceable containers. Containers from which material is occasionally being drawn should be kept tightly closed when not in use. To prevent the accumulation of water in their upper ends, drums should be stored on their sides and their outlets in the up position.

Flammable Storage Areas

On some type ships, special oil and grease lockers are provided for the storage of flammable materials used with ordnance equipments. The inspection, maintenance, and upkeep of these spaces may be the responsibility of ordnance personnel.

Vapors from oils, greases, solvents, and similar products are flammable and, in some cases, may have a toxic effect on the human system. To prevent accumulation of flammable and toxic vapors, storage areas must be properly ventilated. To safeguard against fire and explosion, display warning signs, keep built-in firefighting equipment in proper working condition, and keep interior stowage areas free of fire causing hazards and materials.

A temperature range of 40° to 80°F. is most desirable for the storage of flammable materials. Lubricants and fluids should be segregated from all types of explosives and other dangerous materials.

HYDRAULIC EQUIPMENT SAFETY

If a leak is discovered in one of the hydraulic pipe connections and repair work requires removal of a section of piping or opening a line, the piping or coupling should not be removed without first draining the associated hydraulic system and observing the following safety rules:

1. Shut down hydraulic system before undertaking any repairs.
2. Release fluid pressure before disconnecting any pressure line.
3. Release gaseous nitrogen pressure before disconnecting line to accumulator. Ascertain that system pressure is zero by pressure gage only.
4. Open all doors to a ship's compartment housing pneumatic accumulator systems before venting equipment charged with air or nitrogen to atmosphere.
5. In any hydraulic system, do not allow hydraulic fluids to exceed their working temperature range. Danger of combustion exists when an electric spark is generated in the vicinity of overheated hydraulic fluid.
6. If clothing becomes drenched with hydraulic fluid, change into dry clothing immediately. When in prolonged contact with the skin, hydraulic fluid can injure health.

A mixture of hydraulic fluid and oxygen will explode, resulting in serious or fatal injury to personnel and causing extensive damage to the equipment being serviced. Since nitrogen and oxygen are both furnished in metal cylinders, exercise extreme caution to prevent using the wrong cylinder by mistake: Oxygen always comes in a green cylinder while nitrogen always comes in a gray cylinder with one or two black bands near the top.

UNSCHEDULED MAINTENANCE PROCEDURES

Unscheduled maintenance procedures are actions performed for special ordnance operations such as pre-firing and post-firing tests, battery alignment procedures, system performance tests, and other maintenance actions performed after a major overhaul or repair. System MR cards are utilized for most of the unscheduled maintenance procedures and, in most cases, cover more than one type of maintenance.

Since a gun mount or missile launcher is only one part of a weapon system, they must function properly to ensure maximum system performance. Unscheduled pre-firing maintenance for a gun mount and ammunition loading equipment checks out the mechanical, electronic, electric, and hydraulic components within the gun system for proper operation prior to a firing mission. Other sub-systems of a weapon system such as gun/missile radar, computers, sonar equipment, etc., must also conduct unscheduled maintenance tests to determine their readiness prior to firing. When all subsystems report satisfactory completion of a required maintenance action, the weapon system is then ready to perform its mission.

PRE-FIRING MAINTENANCE CHECKS

Pre-firing checks consist of inspecting recoil systems and counter recoil systems, testing firing cutouts, and limit stop mechanisms, firing primers from both the normal and emergency firing sources, and verifying the safety links and securing pins are disengaged. Pre-operational checks and tests are also conducted on all ordnance units to ensure their operability in all modes of control.

Firing Cutout Systems

There are several different types of firing cutout systems used to protect areas of a ship against accidental firing. One method, called the automatic pointing cutout system, prevents the ordnance units from pointing toward the structure of a ship. The areas of a ship's structure that can be endangered, either through direct physical interference from the ordnance unit or by accidental firing, are called nonpointing zones.

Another method, called the firing stop mechanism (firing interrupter), cuts out (interrupts) the firing circuits whenever the line-of-fire of the ordnance unit nears the ship's structure. The difference between the two systems is that the firing cutout system prevents firing when the ordnance unit is near or pointed into a preset danger sector. The pointing cutout system prevents the ordnance system from training or elevating into a danger zone.

The maintenance methods of these systems differ but basically the pre-firing maintenance test procedures accomplish a ready to fire status for a unit of ordnance equipment. Firing zone parameters (assigned limits) are established by NAVORDSYSCOM for each unit of a weapons system at the time of installation aboard ship and at such other times when the ship's structure is altered near an ordnance unit. The parameters, train and elevation firing zone limits, are recorded in an installation OD for each ship and should be compared when pre-firing checks are conducted. A test lamp, connected by a lead to the terminal of a firing pin mechanism and the other lead grounded, is used on systems where there is no firing zone clear or danger lights installed to determine the conditions of the firing zone cutout system.

Either the test lamp or firing light indicate the condition of a firing cutout system (ON in a clear sector and OFF in a danger sector), and the parameters (train and elevation position readings) determined the safe/danger condition by the light indications.

Most pointing cutout systems use a firing zone clear or firing zone not-clear light to indicate the status of the firing circuit. When conducting pre-fire checks for this type system, a more elaborate check system is used to establish the physical positions of the ordnance units in relation to their firing cutout parameters.

Most ships use a three zone, nonpointing cutout system where each zone has its own set of parameters. Each set of parameters must be checked and recorded every time pre-firing checks are conducted. Since the automatic pointing cutout system prevents the ordnance unit from entering a non-firing zone, the physical position of the ordnance unit must be checked against those recorded in the system installation OD. When approaching a non-firing zone, the automatic limit stop operation takes control of the ordnance unit until such time as the unit is clear of the non-firing zones. The automatic limit stop mechanisms are mechanical, electrical, and hydraulic systems which must be properly maintained through testing and adjusting prior to pre-firing checks. The operation of an automatic pointing cutout system is explained in chapter 6 of this manual.

The firing zone clear and firing zone not-clear lights are used as guides when conducting pre-firing checks and are used to indicate the on/off condition of a firing circuit. Both train and elevation position readings are taken whenever the status of the lights change. A reading is taken when the firing zone clear light goes out and another reading when the firing zone not-clear comes on. This method is used to double check the condition of the firing cutout system by indicating the safe/unsafe condition at approximately the same bearing. In this type system two circuits are used to control the firing cutout system, and both circuits must function within the pre-set parameter limitations. An example of how firing cutout indicating lights help during a maintenance action would be when an ordnance unit is coming out of a non-firing zone condition into a firing zone condition, both lights must indicate a correct status. If one of the lights should indicate a condition not within the pre-set parameters, an indication of problem for the zone being checked could be determined and corrected during a scheduled maintenance action and before a pre-firing unscheduled maintenance action is conducted.

After completion of a firing cutout system check, the firing circuits are then tested by firing test primers at least once from each firing station. On systems using a combination primer (fired by either impact or electricity), the mechanical firing mechanisms are also tested. After the primers are fired, the spent primers should be inspected to ensure that the indentations made by the firing pins are not offset from the center of the primer's base more than the allowable limits listed on a systems MRC pre-firing card.

Limit Stop Systems Testing

A limit stop system provides an ordnance unit with the ability to arrest its movement both in train and elevation at predetermined points before the extreme positive stop, or parameter limits, are reached. A limit stop system does not interfere with the normal operation of a system that is within its normal operating limits. Limit stop mechanisms function in all methods of power operation. Limit stop action depends upon the velocity of an ordnance unit at the instant the limit stop mechanism takes control. The greater the velocity, the sooner the unit stops. The velocity of an ordnance unit helps determine the point at which the traveling stops. This arrangement permits the ordnance units to be stopped smoothly at the same limits of travel irrespective of their velocity as the limit stop position is approached.

Ordnance systems that utilize automatic non-pointing system use a limit stop system in a different way which prevents the ordnance unit from training or pointing into a danger zone. The limit stop mechanism for these systems actuates an override device which causes the ordnance unit to elevate above a danger zone and stops train movement into a danger zone before the present elevation limit is reached. Normal operation resumes when the ordnance unit is trained past or elevated over the affected danger zone. Maintenance of a limit stop system consists of several different electrical, mechanical, and hydraulic tests and adjustments which permit the limit stop system to operate at about 2 degrees away from a positive stop position or a pre-set value from a non-pointing zone parameter setting.

Recoil and Counterrecoil Systems

Pre-firing MR cards require that an inspection of gun recoil systems must be witnessed by a commissioned officer. The inspection ensures that the recoil system is properly filled with recoil fluid and the counterrecoil system's air pressure readings are within their required limits.

Maintenance of these systems, usually on a monthly schedule, requires that the guns be run out of battery and an inspection of the recoil and counterrecoil components be conducted for signs of scoring, galling, and any deformations. After lubrication and cleaning maintenance is performed the guns are run to the in-battery position and the air pressure in the counterrecoil system is charged to its operation levels. Whenever a counterrecoil system is charged, always use air, never use oxygen. Counterrecoil systems are also inspected to ensure that the protrusion of the differential piston is not more than 2 inches beyond packing gland face.

Gun-Barrel Maintenance

The working surfaces of the gun are the interior of its bore and chamber. As time passes and rounds are fired, these surfaces will deteriorate, and require maintenance to ensure their continued usefulness. The main causes of deterioration are erosion, corrosion and dirt, copper fouling, and constriction.

Great heat, great pressure, and complicated chemical changes accompany the burning of the propelling charge. Some but not all, of the residue of the burning is blown out of the muzzle after the projectile. What remains in the gun (powder foulings) is in the form of corrosive salts. Dirt in a gun bore not only encourages corrosion but is a source of danger if it offers sufficient resistance to the projectile.

Standard maintenance procedure (post firing maintenance) is to remove the dirt and foulings by washing out the bore and chamber with a hot soda solution and applying a thin film of oil before securing the gun until the next firing or a scheduled maintenance action.

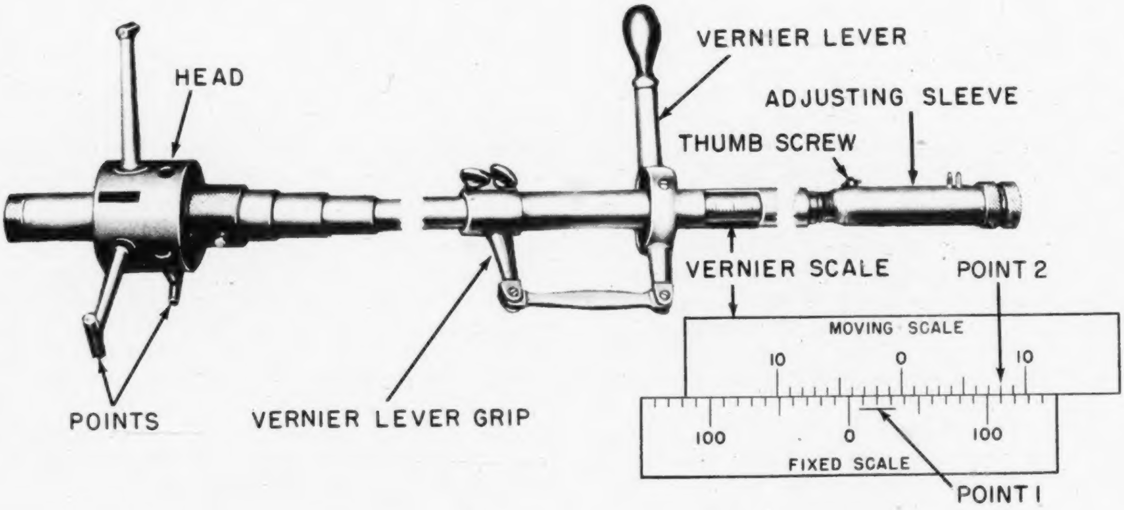
More dangerous than corrosion or dirt is metallic constriction of the bore. Before and after each firing, barrels are tested for this condition with a plug gage. The use of this gage is explained in GMG 3/2, NAVPERS 10185-A.

GUN WEAR

Erosion is the deterioration and wearing away of the bore surface caused by firing projectiles through it. Two measures of gun wear are commonly in use: bore enlargement at the origin and erosion gauge readings. These are separate, independent measures of gun wear but are related to each other. Current NAVORDINST 8300.3 explains the conditions for requesting regunning when either the bore enlargement at the origin or erosion gauge readings reach the condemning point, (80 percent expended). There are two special tools (test equipments) used to measure bore erosion: the star gage and a bore erosion gage.

Star Gage

The star gage (fig. 14-10) consists of a head mounted on a long tube, with metal points 120° apart extending radially from it. These three



110.55
Figure 14-10.—Star gage.

points form a Y and press against the bore of the gun. Points of suitable length are provided for each caliber of gun to be measured. The bases of the points are spring-loaded to bear against a tapered expanding plunger; as the plunger (operated by the vernier lever) moves lengthwise, the points are cammed outward or inward. Measurements are read from the vernier scale.

The vernier scale, provided to measure the amount of movement of the contact points from zero, has a fixed scale and a movable scale calibrated in thousandths and ten-thousandths of an inch. It is read in the same manner as any other vernier scale. Each scale has a central zero graduation (fig. 14-10). To read the vernier, count on the fixed scale the number of graduations the zero on the movable scale has moved to the right or left from zero on the fixed scale. Neglect any partial graduation. Call each graduation ten one-thousandths (0.010) of an inch. Then add to this as many one-thousandths as there are spaces on the moving scale between the zero and that graduation which lines up exactly with a graduation on the fixed scale. In figure 14-10, there are three full spaces on the fixed scale between the fixed zero and the movable zero, (point 1 figure 14-10). This represents thirty thousandths (0.030) of an inch. As you count along the moving scale, you find that the eighth graduation coincides exactly with one of the graduations on the fixed scale, (point 2 figure 14-10). This represents eight one-thousandths (0.008) of an inch. Add this to the other reading, giving a final reading of 0.038 inch.

A testing ring is provided for each caliber gun to be star gaged. The inside diameter of the testing ring corresponds to the exact bore diameter of a new gun (zero erosion). The star gage contacts are set against the inner surface of the testing ring and the vernier scale is set to zero by turning the adjusting sleeve (fig. 14-10) so that the zero marks on the movable and fixed vernier scales coincide. The adjustable sleeve is then locked in place by a thumb screw.

To gage the gun, carefully insert the zeroed instrument into the bore, with the points in an inverted Y, to the first place to be measured. Move the vernier handle until all the contact points touch the gun and take a reading from the vernier scale. Be careful not to apply any more force on the vernier handle than was applied when setting the points in the testing ring. Two star gage readings are always taken at each point of the bore that is measured. The second reading is taken by revolving the gage until the points are in an upright Y position. Whenever the instrument is taken out of the gun, the contact points should be inserted in the testing ring to verify that the vernier scale is still at its zero position. The result of stargaging measurements are reported on NAVORD form 8300/3 (explained in chapter 13).

VELOCITY LOSS ESTIMATION.—Stargaging is performed by highly skilled personnel in tender or shore-based facilities. The object is to measure the amount of erosion along the bore (and especially its origin) so that the corresponding predicted loss in I. V. (initial velocity) can be included in the fire control solution. Tables, charts, graphs, and equations are provided to convert erosion losses into usable I. V. information.

Bore Erosion Gage

The use of star gages with sufficient frequency aboard ship to provide most accurate fire control is not always practicable; therefore, a simple, easy-to-use gage has been developed for use aboard ship by ship personnel without assistance from a tender or yard. Bore Erosion Gage used with the 5"/38 gun system (see figure 14-11) provides indications from which velocity loss can be quickly determined by reference to a set of curves of velocity loss versus gage indications. Bore erosion gages are available for most caliber guns and are used like the one explained here.

The bore erosion gage consists of a gage body, a handle, a brass backing out sleeve, and a handle support. The gage body has three raised external gaging surfaces that are 120 degrees apart and have a diameter of 5.025 inches. The handle is divided into two sections. The forward section is externally threaded at both ends, with the longer threaded section screwed into the gage body and locked in position by a nut. One end of the handle rear section is internally threaded and mates with the forward section of the handle. The other end of the rear section is externally threaded and mates with a backing out collar. Both handle sections are graduated in 5-inch increments, starting with a 20.0-inch marker on the forward section and continuing to the final graduation marker of 50 inches on the rear section. Each graduation marker represents the distance of that marker on the handle from the forward gaging edge of the gaging body.

The brass backing out sleeve is designed to initiate removal of the bore erosion gage from the gun barrel when it is jammed in the bore. This is accomplished by sliding the backing out sleeve forward of the backing out collar and then sliding the backing out sleeve smartly against the collar.

The purpose of the handle support is to center and support the handle in the gun bore and to provide the final portion of the bore erosion gage indication. The handle support

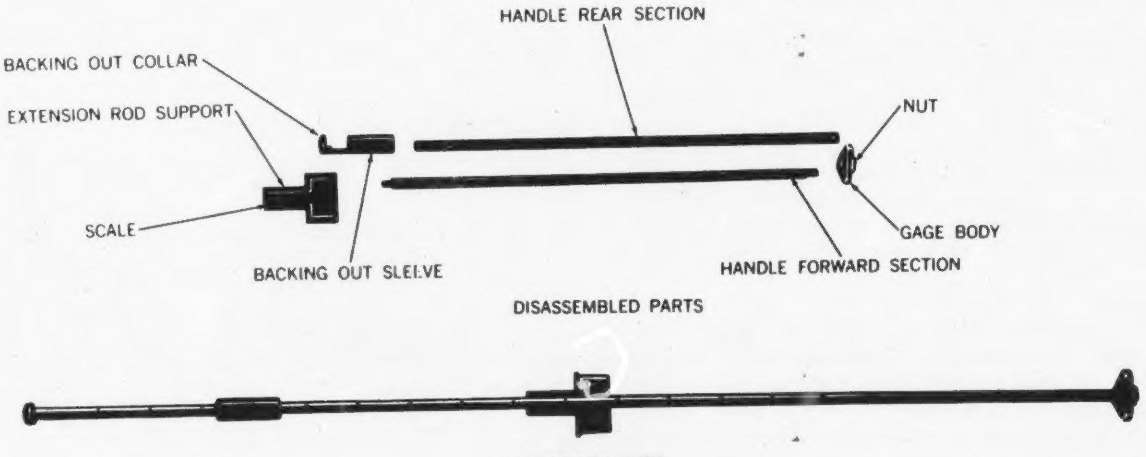


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Figure 14-11.—Bore erosion gage.

is a semicylindrical brass casting which fits closely in the lower half of the gun chamber and has a rim that acts as a stop against the breech face of the gun. A 5-inch scale, graduated in tenths of an inch, is attached to the portion of the support which extends to the rear of the gun chamber. This scale provides the digits for completing the bore erosion gage readings between the handle 5-inch markers.

OPERATION. To use the bore erosion gage, proceed as follows:

1. Clean gun bore and chamber thoroughly. Place gun in battery and attach safety link (refer to chapter 2).

> NOTE: The gun bore and chamber must be cleaned thoroughly to obtain the most accurate bore erosion gage indication. This operation should be performed by three men: one man to push the handle into the gun bore, a second man to take the indication, and a third man to record the indication.

2. Insert bore erosion gage into gun chamber and push handle support into breech until it is flush with breech face. Fit handle into slot of handle support. Place a support block (if available) into gun-loading tray under handle for additional support and to center handle in gun housing.

3. Orient bore erosion gage in gun chamber until one of its pointers is at 12 o'clock position (Y down).

4. Gently push bore erosion gage forward until its pointers contact lands of gun barrel.

5. Pull bore erosion gage to the rear 6 inches.

> NOTE: Do not exert unnecessary force in step 6. The diameter of the bore erosion gage is 5.025 inches and is designed to fit snugly in 5-inch 38-caliber guns.

6. Firmly seat bore erosion gage in gun barrel by thrusting it forward with a single quick motion of short duration. Thrust should have enough pressure to seat bore erosion gage in gun barrel at origin of bore. Thrusting bore erosion gage forward with too much pressure will seat gage forward of origin of bore and provide an inaccurate gage indication.

7. When bore erosion gage has been seated, obtain indication as follows:

   a. Observe handle and record number adjacent to breech face.

   b. Observe handle support scale and observe where marker for number recorded in step 7a bisects scale. Then, record number on handle support scale at that point.

> NOTE: The handle is graduated in 5-inch increments; therefore, when number 45 is outside of gun barrel and number 50 is inside, record number outside of barrel (45). The handle support scale is 5 inches long and each inch is subdivided into 10 parts; therefore, when marker for number recorded in step 7a bisects handle support scale at 2.8, record 2.8.

8. Add both recorded numbers and record sum as bore erosion gage indication Y down. (For example: If 45 was recorded from handle and 2.8 from handle support scale, then Y down bore erosion gage indication is 47.8.)

9. Repeat steps 5 through 8 until at least three consistent indications are obtained.

> NOTE: A slight difference should be obtained in each indication because of the amount of pressure used in thrusting the bore erosion gage into the gun. The same amount of pressure should be used when thrusting the bore erosion gage into the gun to insure that all indications are consistent.

10. Average three consistent Y down sums and record average as bore erosion gage Y down indication.

MAINTENANCE PUBLICATIONS AND NOTICES

System OPs are ordnance publications which describe the physical and functional characteristics of an ordnance system or unit and provide maintenance and operating procedures for personnel assigned to the system. Most system OPs are a series of volumes for each major assembly and an IPB, which is an illustrated parts breakdown publication.

IPB

A system IPB describes and illustrates the parts for a weapon system and is intended for use during corrective maintenance of the subject equipment. An IPB is broken down into sections which identify parts for maintaining the equipment, for illustrating assembly relationships, and for requisitioning repair parts. How an IPB is used for requesting parts is explained in GMG 3/2, NAVPERS 10185.

Illustrations are furnished in sufficient detail to identify all the parts of an assembly and their subassemblies. Many types of phantom views of related subassemblies are also shown to give emphasis when assembling equipment. Also listed in IPBs are applicable publications for additional information on repair, maintenance, adjustments, and safety precautions.

The advantages of using an IPB during assembly procedures is that all related parts are illustrated to show those parts that attach the assembly or group of assemblies to the next higher assembly. By comparing the actual parts of an assembly with those illustrated for that assembly, each part can be easily identified and assembled in the order shown on the illustration. Figure 14-12 illustrates an assembly used in a gun system. It shows all the parts which make up the assembly. If, for example, part number 10 was the part to be replaced, the illustration will help in assembling the unit because it shows how the related parts of the assembly fit together. By following the illustration, each part can be assembled in its proper place within the unit to ensure correct assembly thus allowing the repaired unit to function as designed. There are other publications that can be used for corrective maintenance actions when a system OP does not give enough information or furnish enough illustrations to perform a maintenance task.

SWS Technical Bulletins

Surface Warfare Systems technical bulletins are published about conventional ordnance systems when a maintenance problem caused by a mechanical failure creates concern over a part that might cause damage to personnel and equipment. SWS bulletins are published by NAVORDSYSCOM and explain the purpose, background, and actions which must be taken to either reduce or solve a maintenance problem. They also

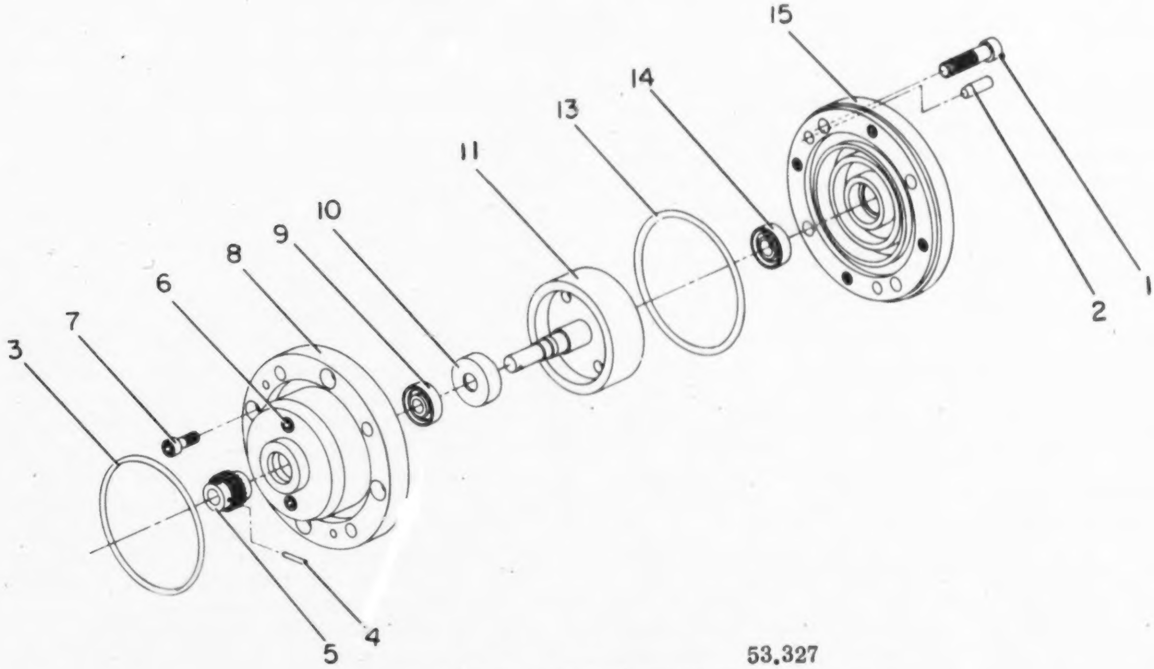

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Figure 14-12.—Train damper assembly.

explain the inspection procedures that must be taken to ensure both safety and reliability of a specific part which may have caused concern so that corrective steps are taken in time to prevent a possible casualty. The action taken from these bulletins is usually incorporated into system OPs in the form of changes. The related MR cards are revised, or an ORDALT may be issued.

An index and status report (SWS Bulletin No. ORD-08-00-000) is issued which lists all SWS bulletins by number and gives a status action taken report for each SWS bulletin. For additional information on SWS bulletins refer to NAVORDINST 5600.5.

RUDTORPE Digest

The purpose of the RUDTORPE Digest is to disseminate authoritative information on safety, training, maintenance, and technical data to help attain and maintain a high level of Antisubmarine Warfare readiness through the discovery and correction of deficiencies arising during service use of underwater weapon systems. This digest is used by personnel maintaining ASROC systems and gives suggestions to improve maintenance methods and tests and also supplies an index of digest publications for each ASW system.

NAVSHIPS Publications

Some ship weapon systems use NAVSHIPS equipments for ammunition handling, magazine firefighting systems (sprinkling systems), and magazine security alarm systems. For maintenance, testing, and operating instructions of this equipment, NAVSHIPS publications are used. An index for these publications is found in Navy Stock List of Publications and Forms NAVSUP 2002.

Index for Conventional Ordnance

NAVORD OD 39397, Index of Technical Manuals for Conventional Ordnance, is a comprehensive source document containing the information most frequently required by personnel concerned with technical manuals relating to installation, operation, and maintenance of in-service conventional ordnance. Information includes listings of conventional ordnance systems and equipments by Mark and Mod numbers and listings of technical manuals by number and short title. In additional to tabular listings, family tree diagrams provide direct correlation between systems, equipments, and publications. This publication is an excellent reference for Ordnance Publications when Index of Ordnance Publications, OP-0, is not available. It is also the only publication that lists Army TMs and FMs used for small arms maintenance.

MAINTENANCE INSPECTIONS

A maintenance program will keep a weapons or weapon system in proper working order as long as a good maintenance crew performs all assigned maintenance actions. To follow a 3-M system program by keeping maintenance records and not performing maintenance actions does not constitute a reliable weapons system. To put a mark in a weekly schedule which indicates a maintenance action when the maintenance was not performed provides for a weak maintenance system.

A good maintenance program can be determined by the down time of the equipment, and material inspections.

Board of Inspection and Survey

The Board of Inspection and Survey conducts material inspections of all newly built or converted ships and service craft, and such other trails and ship inspections as may be directed by the Chief of Naval Operations. There is a statutory requirement that the board inspect all ships every 3 years. Whenever practicable, such inspections are held sufficiently in advance of a ship's regular overhaul to permit accomplishment of work resulting from the board's recommendations. Present policy calls for this inspection to be conducted 4 to 6 months in advance of the scheduled overhaul period.

Prior to inspection, the ship's commanding officer must submit to the board a list of all repairs and alterations he deems necessary. Virtually everything on board must be opened up prior to the arrival on board of the inspecting party — 3-M records as well as all logs and other records. (The material and ordnance histories, and the CSMP ledger must be made available for the inspecting party's examination if these are still being maintained.) The material records will be given a very careful analysis. They must be accurate and up to date.

Upon completion of the inspection, the board will report the general condition of the ship and its suitability for further naval service, together with a list of the repairs, alterations, and design changes which, in its opinion should be made. These reports are made to CNO with copies to the fleet and type commanders. The board's recommendations ordinarily become the basis for work to be done by the shipyard, tender, or ship's force.

INSURV Materiel Inspections are conducted in accordance with statutory requirements of Congress that specify the materiel inspection of a U.S. Navy ship (1) upon the ship's return from a foreign station, (2) at least once every three years (if practicable), (3) when fitness of the ship for further service is in doubt, and (4) when the ship has been declared unfit and stricken from the Naval Vessel Register.

The INSURV Board inspects all parts of the ship including storerooms, magazines, operating spaces, voids, cofferdams, chain lockers, and tanks. The spaces will be opened for inspection in accordance with detailed instructions on the condition sheets. Personnel must be available to open locked spaces immediately upon arrival of the inspection parties. The personnel responsible for a space and the operation of the equipment therein must be present in the space to assist the inspection party by answering questions and operating equipment.

The operational aspects of all equipment and material will be examined during the conduct of the INSURV materiel inspection with the exception of equipment opened or disassembled for a more detailed inspection. Detailed instructions for the preparation of equipment for inspection in each department are included with the condition sheets for the department.

General Inspection Criteria: Weapons

(a) Check the operation and arrangement of all equipment to ensure that the installation will properly support the ship's mission and tasks;

(b) Determine status of spaces assigned to Weapons Department with regard to size, ventilation, air conditioning, lighting, etc.;

(c) Check all safety items pertaining to safety of personnel and materiel;

(d) Check adequacy of maintenance and repair of weapons equipments including maintenance records and implementation of PMS.

Pre-INSURV and Post INSURV Documentation Procedures

The following paragraphs concern normal and general MDCS documentation of INSURV discrepancies. It will be necessary to refer to INSURV and TYCOM instructions for more complete information about the preparation, conduct, and documentation of the INSURV and other material inspections.

a. Pre-INSURV documentation procedures are directly related to the day-to-day documentation of deferred maintenance actions. These deferrals constitute the ship's CSMP which reflects the ship's knowledge of her material condition at the time of INSURV. The "List of Ship Discovered Items" (CSMP) presented to the INSURV inspectors is prepared in one of two ways:

(1) By the TYCOM using the Automated INSURV (Data Processing) procedures. These automated procedures are directly interfaced with the ship's CSMP and depend on proper and timely submission of all maintenance needs (Deferrals).

(2) Hand prepared by the ship. This procedure would also be based on the ship's CSMP and would require that ship's personnel copy all deferrals on to another 4790/2K (No. of copies to be specified by INSURV INST 4730.11).

b. During the INSURV inspection, the INSURV Board members will review all "Ship Discovered Items" and provide information in blocks 44 through 47 on 4790/2K, as appropriate, for each item considered to be a discrepancy.

c. Post INSURV documentation will require that all INSURV-discovered items be documented either as completed maintenance actions or as deferrals as the case may be.

(1) If an item "Discovered by INSURV" is completed prior to end of the inspection, that item should be documented as a completed maintenance action ensuring that blocks 44 through 47 are completed and the inspectors remarks/description are included.

(2) If a "Ship Discovered Item" is modified by the INSURV inspector, that modified item should be documented as a chain deferral. If a "Ship Discovered Item" is completed during the inspection, that item should be documented as a completed deferral. In either case, ensure that blocks 44 through 47 are completed and that the inspectors remarks/description are included.

(3) INSURV inspectors frequently group several discrepancies together as one INSURV Item. In this case, the "Grouped" item would be documented as a deferral with a unique JCN, INSURV classification number (Blocks 44 through 47) and remarks/description as provided by the inspector. Additionally, ship's personnel would document deferrals on each item in the "Group"; each item would have a different JCN, but would reflect the same INSURV classification number as the "Group" item.

RECORDS. — The following records should be available to the inspector upon arrival:

(a) Ship's armament installation list (SAIL);
(b) OAR list if available;
(c) Outstanding Weapons Department CASREPTS and a list of all inoperative equipments;
(d) Current battery alignment data;
(e) Department 3-M data;
(f) Copy of last INSURV report (weapons items only);
(g) Booklet of General Plans;
(h) Applicable NAVORD OD (Test Program for INSURV of Weapons System) is issued;
(i) List of Ship Discovered Items (CSMP)

INSPECTION AND DEMONSTRATIONS. — All weapons spaces except living spaces will be inspected by the weapons inspector. Emphasis will be placed on proper demonstration of equipments and systems. The Test Program outlined in the applicable NAVORD OD will be used as a guide in the conduct of the inspection. Those ships for which a Test Program has not been issued, will be required to demonstrate all weapons systems. This includes inspection/demonstration of all of the following:

(a) Target designation system;
(b) Mount/launcher operation in all modes;
(c) Fire control systems including fire control radars;
(d) Ammunition stowage spaces;
(e) Weapons handling systems including both strike up and strike down facilities;
(f) Magazine sprinkling systems;
(g) Flooding and high temperature alarm systems.

SAFETY SUMMARY

The following are some of the general safety precautions not related to any specific unit of ordnance equipment but recommended for all personnel to understand and apply during test and maintenance procedures.

DO NOT REMOVE OR DISASSEMBLE ANY HYDRAULIC COMPONENT UNDER PRESSURE

Always bleed the hydraulic systems of pressure before attempting to remove or disassemble any hydraulic component. Ascertain that system pressure is zero by gages only. Open doors of ship compartments housing pneumatic equipment before venting equipment charged with air or nitrogen to atmosphere.

EXERCISE EXTREME CAUTION WHEN WORKING IN LETHAL VOLTAGE AREAS

Program with extreme care all work to be performed in lethal voltage areas. Do not work on live circuits unless it is absolutely necessary. Under certain conditions, dangerous potentials may exist in electronic circuits after the power is shut off; when such potentials are suspected, discharge the appropriate components before touching them. Under no circumstances should work be performed in a lethal voltage area without the presence of at least one person capable of giving aid in the event of electrical shock.

RESUSCITATION

Personnel working with or near high voltages should be familiar with the methods of artificial respiration. Such information should be obtained from the Bureau of Medicine and Surgery.

OPERATION OF CONTROL PANELS

Do not allow unqualified or unauthorized personnel to operate the control panels. Trainees or other persons undergoing instruction shall operate panels only under the strict personal supervision of a qualified and responsible operator.

DO NOT SERVICE OR ADJUST ALONE

Under no circumstances should any person reach into any equipment or enter the magazine for the purpose of servicing or adjusting except in the presence of someone who is capable of giving aid.

ESTABLISH COMMUNICATIONS

Do not activate the launching system until communications have been established between the safety observer and the mount captain.

KEEP OPEN FLAMES AWAY FROM EXPLOSIVES

Do not take naked lights, matches, or other flame-producing apparatus into any compartment containing explosives. Smoking is not permitted at any time within these compartments.

HYDRAULIC FLUID HAZARD

If clothing becomes drenched with hydraulic fluid, immediately change into dry clothing. Hydraulic fluid is injurous to health when in prolonged contact with skin. It is also a fire hazard. Immediately wipe up spilled hydraulic fluid.

HIGH-PRESSURE AIR HAZARD

Do not direct a high-pressure air jet at any part of the human body. High-pressure air jets may be fatal.

Remember, The World's Most Important Protective Device Is A Careful Individual.

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